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December 2005
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How John Herschel discovered the southern sky

Someday, we'll hear natural sounds on worlds like Titan and Mars. But scientists have begun listening to songs sung by the universe. p. 36

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OBSERVATORIES SURVEY THE SKY.

COMPUTERS ANALYZE THE DATA.

SCIENTISTS SLEEP.

Meanwhile, some guy named Wolfgang discovers a supernova in his backyard.

We're not saying everyone who buys a new LXD75™ telescope and a Deep Sky Imager™ will discover a supernova their first few weeks out. But that's exactly what happened to first-time astrophotographer Wolfgang Kloehr. Here's his story. ⊙ I owned a small telescope for a long time. But I didn't go out very often. From time to time I wondered how much it would cost to get into astrophotography. Then in May 2005, I discovered the 8" LXD75 and Deep Sky Imager at a small shop in Wurtzburg, Germany. I bought them and started taking pictures.

Five weeks later, on June 27th, 2005, I was comparing some photos of the Whirlpool Galaxy (M51) with ones I had taken earlier when I saw a small bright spot that wasn't there before. I checked all the usual sources for minor planets, supernovae, variable stars, or any explanation of a bright object in M51. There was nothing. Could this be a star exploding in a distant galaxy? I had to find out. For the next few nights I fought cloudy skies to confirm the discovery.

My first ever dispatch to Dan Green at CBAT (Central Bureau For Astronomical Telegrams) went as well as could be expected. Mr Green patiently explained that I needed to provide better coordinates and more positive confirmation photos. I was new to this.

When the weather went from bad to worse, I figured my chance for a first discovery was gone. Someone was bound to have seen this bright new thing by now. On June 30th, the sky cleared just long enough to get another photo. I submitted it and got an immediate email response.

The heading announced a new supernova (SN 2005cs in M51). Two independent sources in the U.S. and Japan had confirmed the discovery. Was I the official discoverer? Was my name included in a long list of discoverers? Did I even make the list at all? I found the supernova on the International Astronomical Union bulletin and scrolled to the column "Discoverer." There was only one name: Wolfgang Kloehr.

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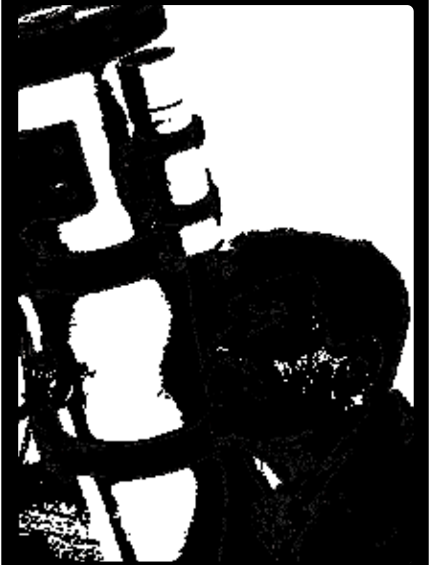

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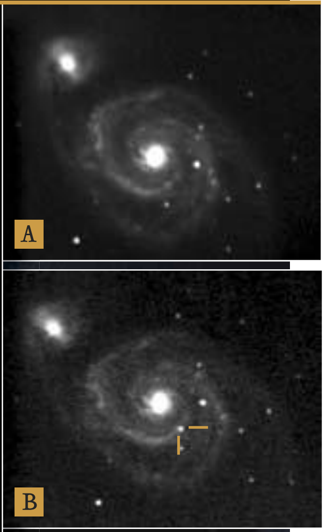

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MICHAEL CARROLL FOR *ASTRONOMY*; INSET: BILL AND SALLY FLETCHER

ON THE COVER

Sound occurs anywhere pressure waves can travel. Whirlwinds howl on Mars. Thunderclaps and volcanic eruptions may occur on Saturn's moon Titan. We can see the Sun and stars oscillate from sounds trapped within them. And the cosmic microwave background sings the universe's birth cry.

Astronomy

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VOL. 33, NO. 12

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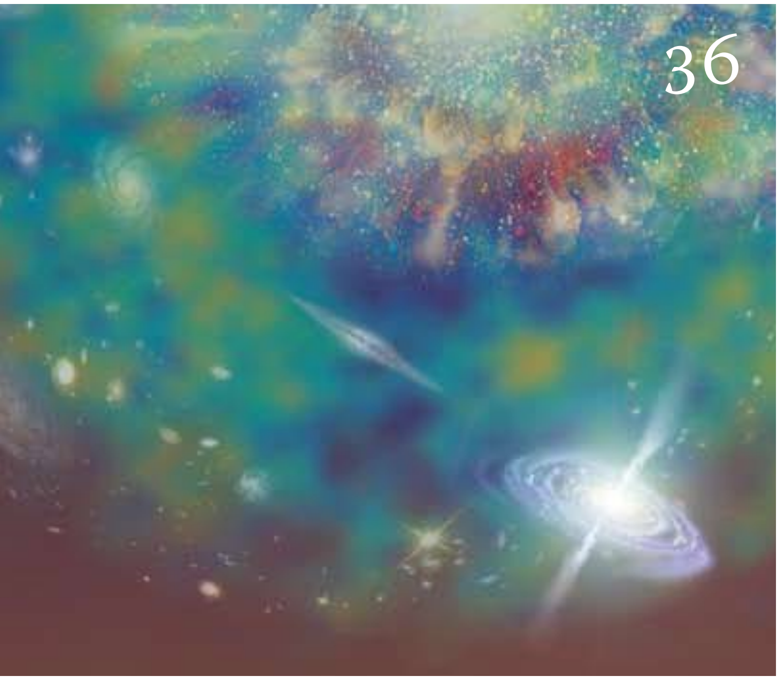

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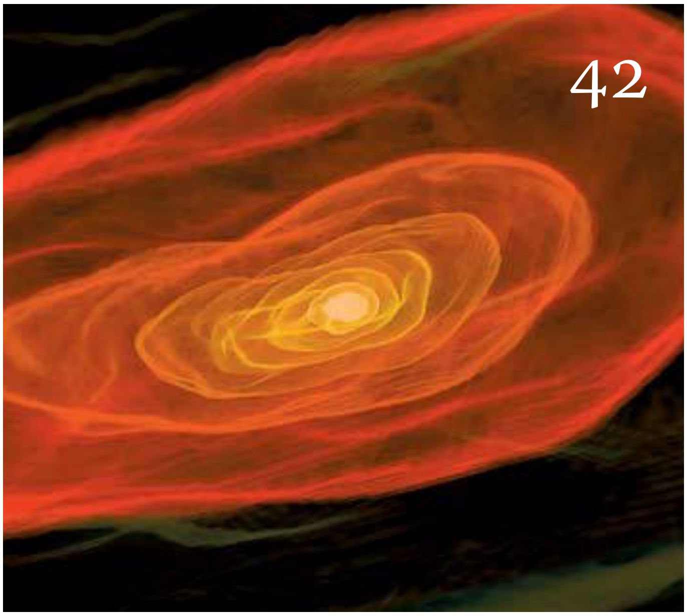

TOM ABEL ET AL.

06 This month in *Astronomy*
Helloi goodbye

14 Beautiful universe

16 Letters

1 Bob Berman's strange universe
Seven holiday secrets

20 Glenn Chaple's observing basics
Blinded by the moonlight

22 Phil Harrington's binocular universe
A visitor's guide to the Andromeda Galaxy

ONLINE EXTRA: Explore more galaxies with your binoculars.

24 News
- A supernova's colliding winds
- NASA's storm watch
- Mars Express looks into curious crater bulge
- First triple-asteroid system found

36 COVER STORY

The music of the spheres
Space is alive with the "sound" of solar flares, black holes, and even the Big Bang. ALISON BOYLE AND KEN GRIMES

ONLINE EXTRA: Listen to the sounds of space.

42 In search of the first stars
Detecting the first stars will help astronomers unlock secrets of the infant universe. RAY JAYAWARDHANA

ONLINE EXTRA: See more computer simulations of the first stars.

48 The man who doubled the sky
In 1833, John Herschel's family name took him to South Africa to map the southern sky, and his determination made him a legend. ROBERT ZIMMERMAN

ONLINE EXTRA: Read some of John Herschel's journal entries.

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54 Odd couples

From near Earth to beyond Pluto, binary asteroids are everywhere in the solar system. DAN DURDA

ONLINE EXTRA: A scientist recounts finding the first asteroid moon.

60 The sky this month

Planets on parade

MARTIN RATCLIFFE AND ALISTER LING

72 A comet's tale

Astronomy takes you from a comet's nucleus to the complex interactions in its dust and gas tails. RICHARD TALCOTT

76 Explore winter's overlooked nebulae

Glowing gas clouds scattered along the Milky Way offer challenges for backyard observers. STEVE COE

ONLINE EXTRA: View a gallery of spectacular nebulae.

82 Ask Astro

84 Around the universe with a 3-inch scope

Under a dark sky, even a small telescope reveals the wonders of the cosmos. RAYMOND SHUBINSKI

90 The eyepiece that changed observing

Tele Vue's introduction of the Nagler eyepiece 25 years ago started a revolution in high-quality optics.

MICHAEL E. BAKICH

98 Follow the daytime star

Set up this simple solar viewer, and you're sure to attract a crowd. RAYMOND SHUBINSKI

104 New products

108 Coming events

109 Advertiser index

117 Reader gallery

GEORGE GREANEY

SID LEACH AND WIL MILAN/ADAM BLOCK/NOAO/AURA/NSF

PAOLO CANDY

BY DAVID J. EICHER

Hello, goodbye

Change is inevitable at every organization, even when it means saying goodbye to colleagues who will be sorely missed. Such is now the case at *Astronomy*, where our publisher, JamSs Slocum, is retiring after a distinguished career at Kalmbach Publishing Co.

Following a long newspaper journalism career, Slocum joined the company as editor of *Model Retailer* in 1995.

Two years later, he also became the magazine's publisher. In 1998, he relinquished editorial duties and was named publisher of *Bead&Button*, *Dollhouse Miniatures*, *Trains*, and Kalmbach's book division, as well as *Model Retailer*.

Later that year, Slocum was named vice-president of editorial and Kalmbach's corporate secretary. He spearheaded the teams that conceived and launched two of Kalmbach's successful newer magazine titles, *Classic Trains* and *BeadStyle*.

Since then, he has published many titles, including *Astronomy*, *FineScale Modeler*, *Model Railroader*, *Scale Auto*, and *Birder's World*. "It's been fun," says Slocum. His enthusiasm, sense of exploration, and wisdom will be missed around the office.

Astronomy's new publisher, Kevin Keefe, brings great energy and excitement for the subject to this role.

Keefe studied journalism at Michigan State University, graduating in 1973, and embarked on a newspaper career. He worked at three daily newspapers in Michigan before joining the staff of *The Milwaukee Sentinel* in 1980. He worked at *The Sentinel* for 7 years, mostly as arts and entertainment editor.

He came to Kalmbach in May 1987 as an associate editor of *Trains* magazine, a publication he has read since he was 14.

In 1992, Keefe became editor of *Trains* and served in that capacity until 2000, when he was promoted to associate publisher. Now, Keefe's responsibilities as publisher include *Astronomy*, *Birder's World*, *Model Retailer*, *Trains*, and *Classic Trains*.

Keefe and his wife Alison live in Milwaukee with their two children.

ASTRONOMY: WILLIAM ZUBACK

Meet *Astronomy's* new publisher, Kevin Keefe.

In addition to Slocum, we bid farewell this month to another team member Senior Editor Robert Burnham.

He is leaving the magazine to accept a job with Arizona State University as manager of media relations and marketing for its newly expanded Mars web site, themis.asu.edu. (THEMIS, the Thermal Emission Imaging System, is a principal instrument aboard Mars Odyssey, now in orbit about the Red Planet.)

"The site aims to be *the* Mars web site," says Burnham. "There will be a heavy emfhasis on the general public, although the site will also serve teachers, students, and professional scientists."

Burnham joined *Astronomy* in 1978 and left the magazine in 1986 before returning in 1988. He became editor in 1992, leaving again in 1996 and returning in 2003. His interest in Mars, planetary exploration, and solar system astronomy in general always guided the magazine, and his contributions will be missed.

Yours truly,

David J. Eicher
Editor

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Volume 33, Number 12

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SolarMax 70 CaK

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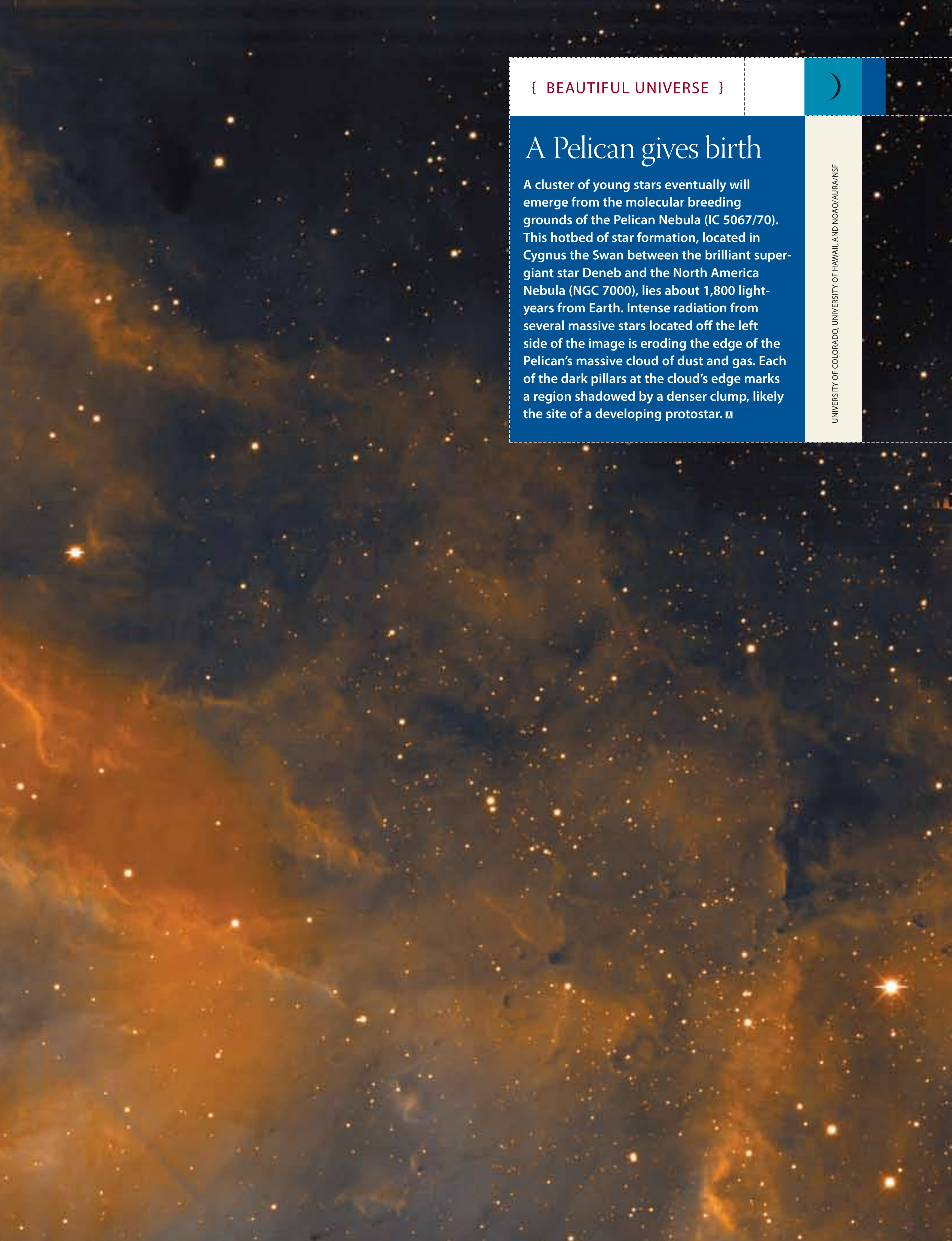


{ BEAUTIFUL UNIVERSE }

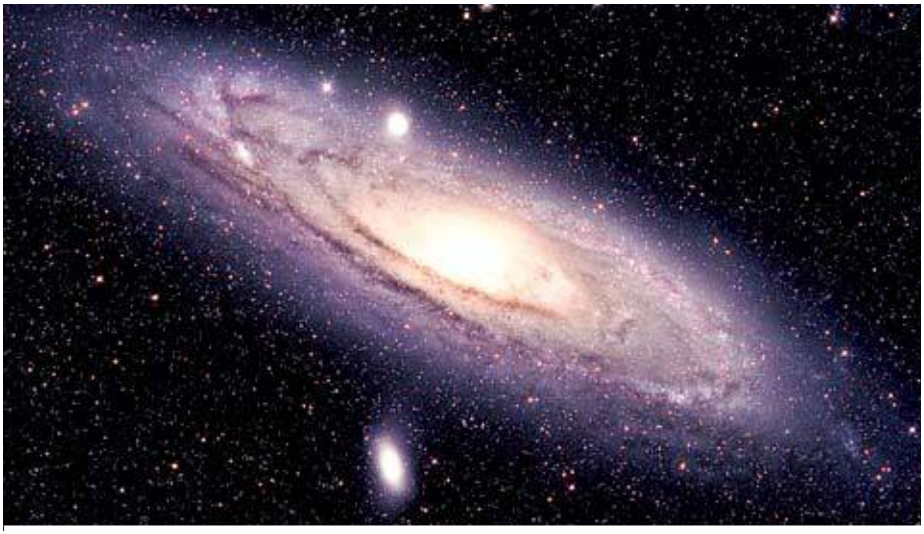
A Pelican gives birth

A cluster of young stars eventually will emerge from the molecular breeding grounds of the Pelican Nebula (IC 5067/70). This hotbed of star formation, located in Cygnus the Swan between the brilliant supergiant star Deneb and the North America Nebula (NGC 7000), lies about 1,800 light-years from Earth. Intense radiation from several massive stars located off the left side of the image is eroding the edge of the Pelican's massive cloud of dust and gas. Each of the dark pillars at the cloud's edge marks a region shadowed by a denser clump, likely the site of a developing protostar.

UNIVERSITY OF COLORADO, UNIVERSITY OF HAWAII, AND NOAO/AURA/NSF

Final approach

In the September 2005 issue, two articles mention the Andromeda Galaxy's radial velocity on its approach to our Milky Way; that is, the relative velocity between the two galaxies. Elisabeth A. Benchich's "What happens when galaxies collide?" gives this velocity as about 100 kilometers/second, while in "How the universe has surprised us," Marcia Bartusiak and Stephen Lowe give this velocity as 300 km/s. This is a huge discrepancy for a value that should be well established by astronomers. — **KEN DIXON,** TORONTO


JASON WARE

THE ANDROMEDA GALAXY (shown here) is speeding toward the Milky Way. In roughly 2 billion years, the galactic giants will begin to merge. Several passes will strip stars out of the galaxies' halos, and, eventually, the pair will become a single elliptical galaxy.

It turns out — strange as it may seem — both numbers are correct.

In "How the universe has surprised us," the authors were talking about Vesto Slipher's first measurements of M31's radial velocity. He found its radial velocity to be about 300 km/s relative to our solar system. Remember, at the time, M31 was thought to be part of the Milky Way, so that was the only reference that made sense.

The difference in the two numbers arises because the solar system is not stationary with respect to the Milky Way. It's located about 30,000 light-years from the galaxy's center and takes about 250 million years to make one revolution. If you do the math, you'll find the solar system revolves around the Milky Way's center at roughly 225 km/s.

M31 lies in such a position that most of the solar system's motion is away from it. So relative to the Milky Way's center, M31 is approaching at about 100 km/s.

Because the eventual collision of the two galaxies depends on the relative motions of their centers of mass, that was the number quoted in the other article, "What happens when galaxies collide?"

Thanks for your letter — it keeps us on our toes to know our readers care enough to read the magazine so thoughtfully.

RICHARD TALCOTT, SENIOR EDITOR

Reality check

I think Julius Wroblewski is looking to the future of space travel in a realistic manner (Letters, September 2005).

Our space abilities are analogous to walking it — instead of driving — to distant cities in North America.

When we can get into space in an inexpensive way and travel at a [illegible] speed equal to the speed of light, then we will be ready for more space travel.

Going to Venus, taking 3 years to go and [illegible] come back, is not practical by any means.

— **ROBERT NICKELS,** MACK, COLORADO

Four no more

In "You do the math" (September 2005), Bob Berman singles out the number 4 as having a special place in our astrophysical numerology. But there are:

- 3 flavors of quark (up/down, charm/strange, top/bottom)
- 3 colors in quantum chromodynamics (blue, green, red)
- 3 particle generations (electron, muon, tauon)
- 3 types of particles (quarks, leptons, force carriers)
- 3 physical dimensions (time being non-physical)
- 3 intermediate vector bosons (W^-, W^+, Z^0)

It seems to me 3 is far more fundamental than 4. Mundane? I think not! — **DANIEL A. MORGAN,** MERCER ISLAND, WASHINGTON

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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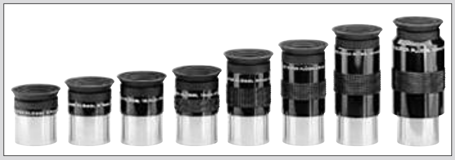

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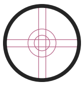

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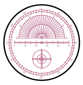

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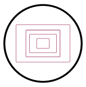

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{ BOB BERMAN'S STRANGE UNIVERSE }

BY BOB BERMAN

Seven holiday secrets

My phone rings a lot in December. The voices are those of friendly strangers wanting advice about buying a telescope for a geeky loved one. ☾ I tell them the same thing you would tell them. One size doesn't fit all. Need portability? Get a Schmidt-Cassegrain (SCT). Plan to spend a few grand? Get a 10-incher with all the gadgets. On a budget? Go for a Dob. Does the recipient value craftsmanship over light-gathering power? Get a Maksutov. Is this an all-thumbs person incapable of mirror collimation? Choose a 5-inch refractor. Got a permanent site for a roll-off shed? Spring for a 10- or 12-inch f/6 Newtonian. Need something indestructible for a child, or a scope for under $250? Get a 60- to 80-millimeter refractor with 1¼" eyepieces, and upgrade to a decent 50mm finder.

"Go-to" models are popular. But impatient adults fumble around with them, unwilling to do the start-up steps where you aim it at a few famous stars and press buttons. Such restless beginners should probably get GPS models.

But hold on. This is "Strange universe." What's strange about beginners getting a first telescope? Answer: the seven secrets.

If someone you love hints for a telescope, break the news to them about these hidden realities of backyard astronomy.

1. Few objects in the universe look spectacular through average telescopes.
People imagine their new scope will be a magical portal to colorful, swirling nebulae and gold-and-blue spiral galaxies. Um, not quite. Serious observers are happy with faint, colorless smudges because they're thrilled to behold a galaxy 50 million light-years away. But beginners, recalling magazine photos, expect countless Hubble-like galaxies bedecked with spiral arms.

So what makes newbies gasp at the eyepiece? The non-Full Moon, Saturn, Jupiter, and the Hercules Cluster (M13). Maybe the Orion Nebula and a few others. A sustained appreciation for the rest requires a serious relationship with astronomy. If this is a lark, an impulse, it's best not to overspend.

2. It's a black-and-white universe.
Sure, you'll find a few pastel binaries like Albireo. And Mars is yellow-orange. Uranus and some planetary nebulae are greenish.

> When a 12-inch scope points one-third of the way up the sky, it's looking through 30 pounds of swirling gas.

But that's about it. New backyard observers expect a gardenlike cosmos of vivid rainbow colors, and that's not going to happen.

3. You can't just point a telescope anywhere and see something interesting.
Raw beginners think the sky is crammed with goodies like the shelves of a supermarket — there's a reason it's called "space."

4. Everything's blurry most of the time.
That's just how it is. Only the degree of smudginess varies. And no wonder: When a 12-inch scope points one-third of the way up the sky, it's looking through 30 pounds of swirling gas. Thirty pounds! Miles of air! You and I are used to it; we simply wait for the moments when the seeing steadies and we ignore the rest. We also know enough to "use low power when the seeing's sour." Speaking of which:

5. Low power is usually better.
As longtime director of two observatories, with 33 years of guiding the public on endless viewing nights, using 6- to 40-inch instruments, I employ magnifications below 100x half the time, and below 180x ninety percent of the time. But beginners reach first for a high-power eyepiece; that is, if they can even figure out that it's the one with the lowest number written on it.

6. A planet-observing session means staring like a catatonic for an hour or more, waiting for moments of exquisite seeing.
Beginners imagine one merely points the scope at a planet and *Wham!*, you've got it. Observers from Galileo onward have learned otherwise.

7. Telescopes work poorly on wooden decks, and you can't point them out windows, open or shut.
They must be hauled out and in. Chiropractors love backyard astronomers; we help put their kids through college.

You and I have gotten past these misconceptions, so let's help the newbies whose observing world seems as confusing as string theory.

Then they can move on to steps two and three: coming to grips with constellations that bear no resemblance to anything whatsoever, and stars whose names are more easily pronounced by growling dogs.

Happy holidays, and welcome to the strange universe. ■

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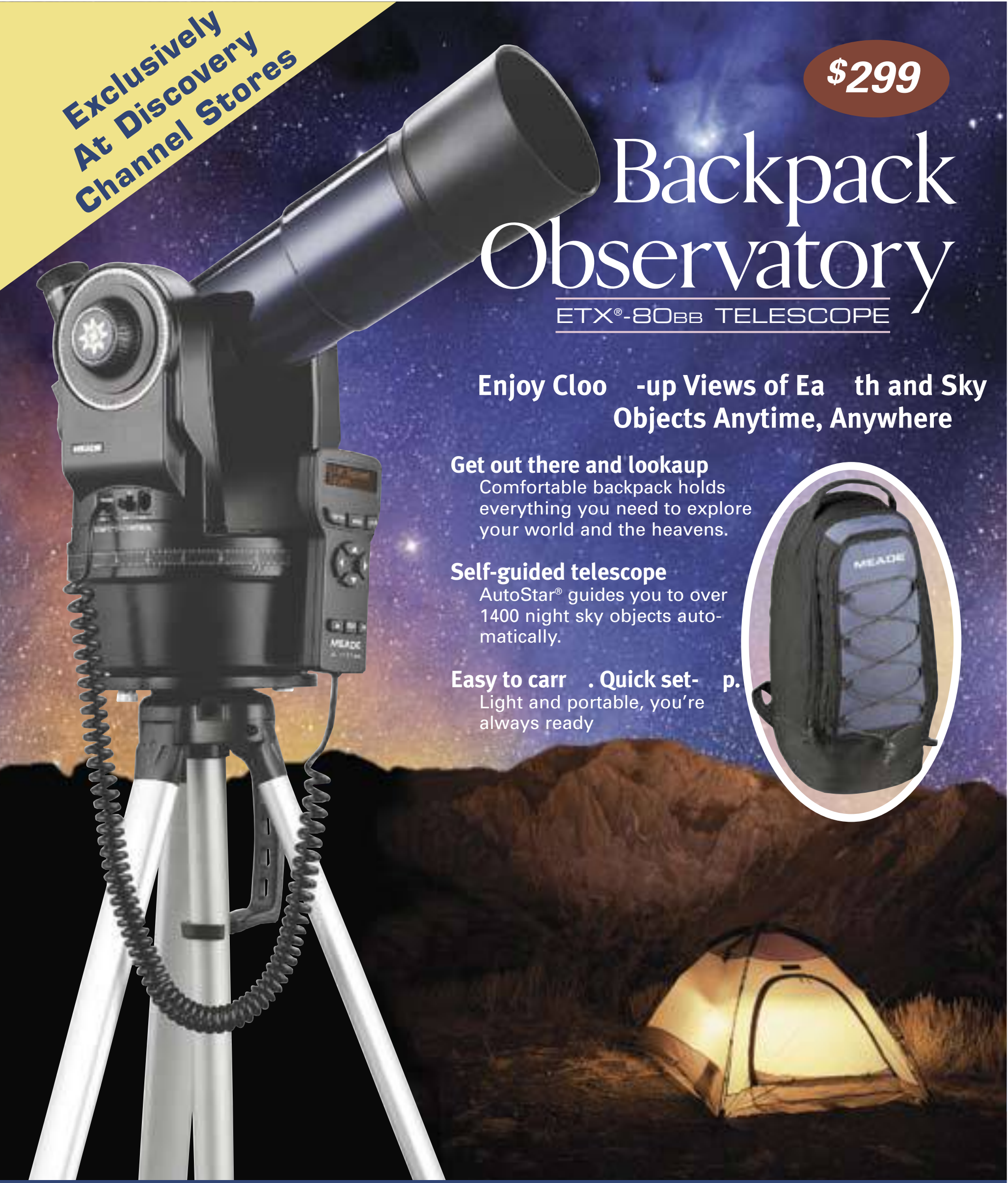

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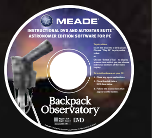

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BY GLENN CHAPLE

Blinded by the moonlight

Would you attend a Fourth of July fireworks display if it were held at midday? Probably not. The midday Sun would all but obliterate the event. For a similar reason, skygazers tend to pass up meteor showers that occur around Full Moon. Bright moonlit skies hide fainter meteors, diminishing the visual impact of these cosmic fireworks.

Such is the case with this year's Geminid meteor shower. Among the richest and most reliable of the annual meteor showers, the Geminids are expected to reach peak activity the evening of December 14. Unfortunately, a nearly Full Moon will be on hand to spoil the fun. But even if you're not a meteor aficionado, step outside for 15 to 20 minutes, just to see what's going on. Meteor showers can be unpredictable, and you never know what you'll see.

We'll have better luck with the Ursids. This meteor shower tends to fall under the radar for two reasons. It's a relatively minor event, averaging a mere 10 meteors hourly (although brief outbursts of 50 or more per hour have been reported), and it occurs at a time of year when most of us are caught up in the holiday rush. I've never witnessed an Ursid meteor for the aforementioned reasons, plus clouds have foiled my efforts in recent years. Weather permitting, I'll be outside the evening of December 22, reclining in a lawn chair and bundled up against the cold as I gaze northward toward the shower's radiant: Beta (β) Ursae Minoris. A bright gibbous Moon won't rise until nearly midnight, so I'll have several hours to capture my first Ursid. Because I'm competitive, I challenge you to an Ursid meteor count — who sees the most in a single hour. Any takers?

MERRILL CLARK

AS BEAUTIFUL as it is frustrating, the Full Moon's brightness hides many "shooting stars" and other night-sky favorites.

A few gift ideas

Visit Astronomy.com to read my review of the book *The Stargazing Year* by Charles Laird Calia. A delightful, fact-filled, month-by-month romp through our night skies, as well as a humorous account of the author's attempt at constructing an observatory, *The Stargazing Year* is a must-read for novice and experienced skywatchers alike. After you buy Calia's book, be sure your subscription to *Astronomy* will carry you through until the end of 2006.

Finally, pick up a copy of our annual guide, *Explore the Universe 2006*. As the New Year arrives, read Calia's chapter on January. Use the all-sky map from the January issue of *Astronomy* to locate the sky sights Calia describes and the January notes from *Explore the Universe 2006* for enrichment. Then, go outside and get to know the heavenly wonders that greet our eyes that month. Do the same in February and ensuing months.

I recommend this tactic for the beginner eager to learn about our night sky's stars and constellations. But you veterans might enjoy reviewing old night-sky friends as Calia presents them.

The great Mars hoax of 2005

As I reflect on the past year, I'm amused by the fact that the biggest astronomical event of 2005 never happened — at least, not in 2005. Early last summer, several readers e-mailed me inquiring about an unusually close August opposition of Mars they had heard about. One report claimed that, to the unaided eye, Mars would appear as large as the Full Moon! Locally, several acquaintances, including my brother, asked me about this story. I was surprised because Mars was due for an opposition, but not until November. Were the heavens suddenly coming undone? A little detective work provided the answer.

Apparently, descriptions of the close opposition of August 2003, still out there on the Internet, confused people who didn't read the date carefully. The result was a false rumor — NASA ultimately called it the "Mars hoax" — that a great opposition would occur in August 2005. Lesson: Read carefully any astronomical info gleaned from the Internet. Better yet, check out www.astronomy.com for the real story.

Next month: We explore the Moon and take a "power trip." Clear skies.

POP QUIZ

Here's one for you astronomy trivia buffs. While the debris associated with most meteor showers comes from comets, the Geminids are an exception. What is their source? (Answer next month)

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GP-D2 Equatorial Mount

Deluxe Equatorial Mount

Geared for those seeking a portable, high-precision mount for astrophotography or simply visual observing, the GP-D2 is the perfect platform for more than just Vixen telescopes! Accurate tracking is achieved with dual 144-tooth brass worm wheels and gears. The R.A. worm is machined to 0.001 mm tolerance for accurate tracking, and all worm gears are individually inspected before assembly in Japan. Die-cast aluminum pares the weight of the GP-D2 down to 18.7 lbs. yet the design permits a carrying capacity of 22 lbs. Manual slow motion controls are provided.

R200SS 8" f/4 Richfield Newtonian

Advanced Imaging & Visual

At f/4 there's no room for error when forming the surface of a parabolic mirror. Vixen's solution is to execute each R200SS mirror with its High-Precision Poly-Order Aspherical Mirror Molding Technique. The result: exquisite state-of-the-art paraboloid form. Compact 28" length and only 11.7-lbs, the large 60mm drawtube allows for a whopping 2.6° x 1.7° field-of-view on 35mm format. The perfect imaging mate for the GP-D2 equatorial mount.

Recommended Accessories

Coma Corrector

Eliminates coma in full-frame imaging. Can be left on for visual use.

LV Eyepieces

25
10
5
(32x)
(80x)
(160x)

Our famous Lanthanum eyepieces are fully multi-coated with huge 20mm eye-relief for comfortable observation and easy eyepiece projection planetary imaging.

SPHINX Equatorial Mount

"Vixen's newest go-to mount is a winner." — Astronomy

SPHINX mount with its Internet upgradable STAR BOOK controller, is the culmination of a decade of design experience. SPHINX responds nimbly and precisely to your commands due to its lightweight design with low-rotational momentum. STAR BOOK is striking with its 4.7" LCD screen and powerful CPU that produces localized star charts with Constellations, "goto" menus for 22,725 celestial objects: Messier, NGC/IC, Solar System, stars, and more. Auto-guider port works with SBIG guiders. Mount is controllable through popular planetarium programs such as *TheSky6* (*Serious* or *Pro*) and *Starry Nights* (*Pro* or *Pro Plus*).

The Reviews are In: "A telescope mount for the 21st century"

Astronomy magazine, November 2005

- "The Star Book is so easy to operate it flirts with user-interface perfection ... ."
- "As it stands now, the Sphinx is by far the easiest-to-use go-to mount."
- "Those interested in imaging should give this mount consideration."
- "The Sphinx is an extraordinary value because this amount of periodic error is normally encountered only in mounts 4 or 5 times its cost."
- "More good news: The mount is terrific."
- "To its credit, the screen worked well even at low temperatures — I subjected it to a test at -15° Fahrenheit (-26° Celsius) one night... ."

Recommended Accessories

Polar Axis Scope

6x20mm
for both hemispheres

Aluminum Case

Holds SPHINX, STAR BOOK, weights, battery case and more.

Tripod Carry Bag

Includes half-pillar pouch.

PORTA Alt-Az Mount

PORTA: Exceptionally Portable Mount!

Newly designed friction system for quickly pointing toward the object and hand tracking it with the 360° slow-motion controls. No fumbling with clutches or sectional slow-motion controls! Leave the counter-weights with the equatorials: simply balance scopes up to 9-lbs. on the altitude axis and start viewing! Standard Vixen dovetail mounting slot with lock and safety screw is fully SPHINX/GP-compatible. PORTA mount features interchangeable slow-motion knobs, tension adjustment and disassembly tools, built-in tool storage bay, tripod tray and aluminum legs.

ED80Sf 80mm f/7.5 APO Refractor

Portable Affordable APO

Breakthrough price on an ED80Sf scope package including giant 9x50mm finder, dual T-thread flip-mirror with 1¼" eyepiece adapters, rotatable 2" eyepiece adapter with locking collar, Crayford focuser with tension/lock adjustment, tube rings with dovetail plate and telescope/accessory travel case! Included standard accessories make the ED80Sf the value leader in affordable 80mm APO scopes. Perfect size for PORTA mount makes this an exceptionally portable system.

Recommended Accessories

SX Camera Adapter

For eyepiece projection with flip-mirror and T-Ring.

LV Eyepieces

40
8
4
(15x)
(67x)
(150x)

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BY PHIL HARRINGTON

A visitor's guide to the Andromeda Galaxy

Like many of you reading this, I'm a longtime fan of the original *Star Trek* series. One of the more unusual episodes to come out of its second season was titled "By any other name." In this installment, the Kelvans, an advanced race who had only recently assumed human form for their devious purpose, commandeered the *Enterprise*. As the rest of the crew was reduced to small cubes of chemicals, Kirk, Spock, McCoy, and Scotty were left to pilot the *Enterprise* toward the Kelvans' home in the Andromeda Galaxy.

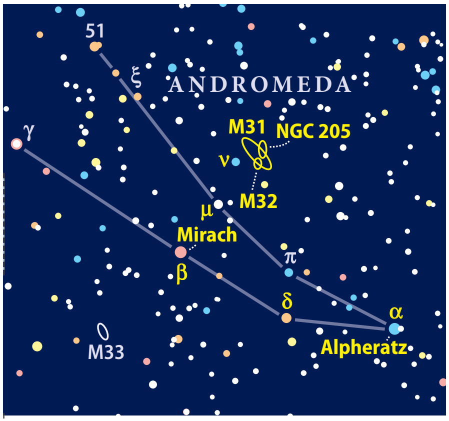
Even with modifications, the *Enterprise* would take 300 years to make the trip. The story ended with our fearless foursome overpowering the Kelvans by using their newly discovered human senses and emotions against them.

That episode probably introduced more people to the **Andromeda Galaxy** (also know as M31) and its vast distance from Earth — 2.5 million light-years — than all of the books and articles written about it.

The idea that it would take a supercharged *Enterprise* 3 centuries to get there points to intergalactic space's enormity. Yet tonight, with just our eyes and clear conditions, we can watch this galaxy approach the sky's zenith (the point in the sky directly overhead). Light-polluted skies might hide M31 from naked-eye view, but carefully aimed binoculars can still spot it.

To find M31, first locate its home constellation, Andromeda the daughter of Queen Cassiopeia. Imagine Andromeda sharing the star **Alpheratz** with Pegasus.

From Alpheratz, slide about one binocular field northeast, to the faint star **Delta (δ) Andromedae**, and then another field farther northeast to **Mirach**.



ASTRONOMY: ROEN KELLY

USE THIS FINDER CHART to help you locate M31's galactic groupies.

Take a sharp right turn northwestward, first stopping at **Mu (μ) Andromedae** and then onward to **Nu (ν) Andromedae**.

Finally, look just northwest of Nu for a dim, elongated blur. It may not look like much at first, but you've found the Andromeda Galaxy, the combined light of several hundred billion suns. That starlight traveled for more than 2 million years just to reach your eyes tonight!

The Andromeda Galaxy is the closest major galaxy to our Milky Way and the brightest visible from the Northern Hemisphere. Binoculars show it as a broad, oval smudge of grayish light highlighted by a prominent core. How much of the galaxy your binoculars will show depends on sky clarity and darkness. Only its bright central nucleus can pierce severe light pollution. From a dark, rural location, you can see the full span of the extensive spiral-arm disk. M31 reaches out as far as 5° — that's as wide as 10 Full Moons stacked end to end!

Had Captain Kirk and company continued on their intergalactic trek, they would have noticed Andromeda's galactic groupies. You can spot M31's two largest satellite galaxies through binoculars, although each will push your limits. The smaller and brighter of the pair, **M32**, can be spotted as a starlike light patch due south of M31's central core. The second companion, **NGC 205** is larger, fainter, and more difficult to observe. Look for it to the north of M31's core, about twice as far as M32. Both are classic examples of dwarf elliptical galaxies. M32 looks almost circular, while NGC 205 is more oblate.

M31 is a real treat through binoculars, but let us consider this as we gaze contemplatively toward this distant island universe: A civilization like the Kelvans might be staring back at us through their own binoculars, wondering if you and I exist.

The Andromeda Galaxy may be the brightest, but it is certainly not the only galaxy visible in tonight's sky. Be sure to stop by Astronomy.com this month for a list of others that await you. Then, join me here next month, as we move northward to Perseus, the mythological hero who rescued the princess Andromeda from the jaws of death. Till then, remember that two eyes are better than one.

ONLINE EXTRA any more galaxies are visible through binoculars besides Andromeda. A list of such impressive targets is available at www.astronomy.com/toc

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Panoptic 68°
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Radian 60°
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Plössl 50°
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— S&T

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"Optics don't get any better than this." — Backyard Astronomer's Guide

Tele Vue-NP127
127mm 4-element APO, f/5.2
Big brother of the NP101. "There isn't a better 5" refractor built." — C.J. (customer)

TeleVue Visionary

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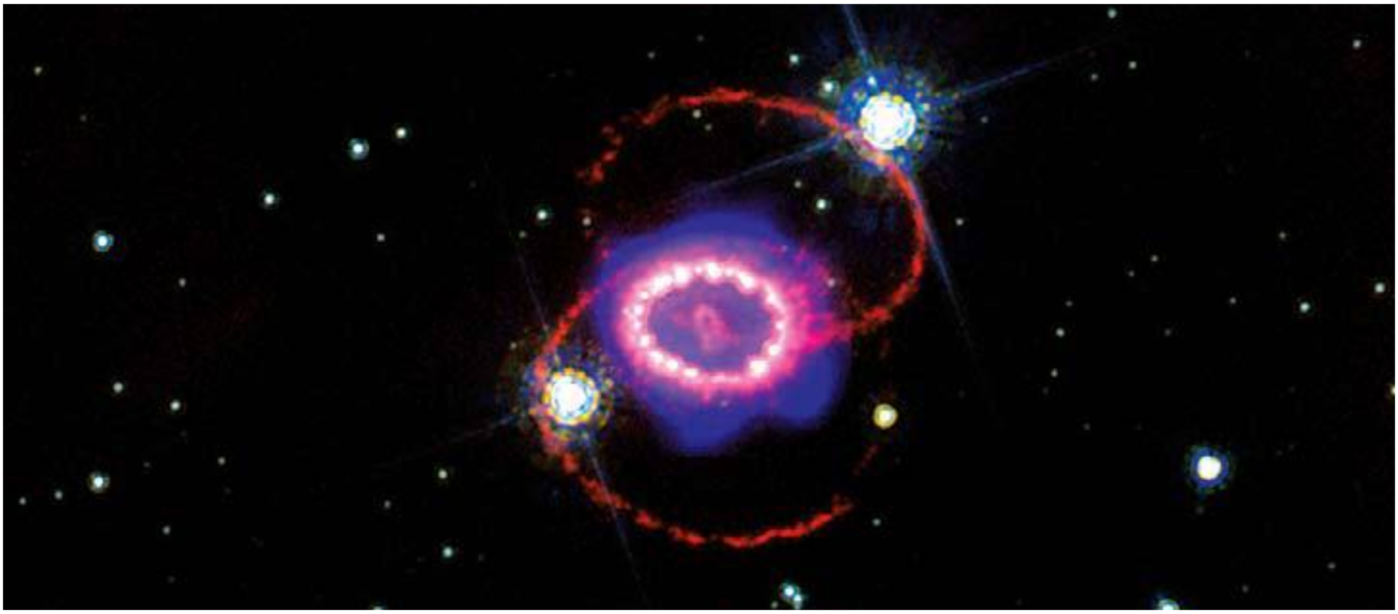
FROZEN LIGHT. Physicists in Australia have stopped light for more than a second. The beam passed through a special material that recorded its characteristics as spin changes in the solid's atoms (August 5, 2005, *Physical Review Letters*).

news 12

Handwritten Einstein manuscript discovered, Earth's core spins faster than its surface, hurricanes disrupt return to flight, Hubble may get a new lease on life



X RAY: NASA/CXC/PSU/S. PARK & D. BURROWS; OPTICAL: NASA/STScI/CfA/P. CHALLIS

COLLISION COURSE. Optical hotspots and a glowing X-ray ring are the results of a supernova shock wave colliding with material ejected before the blast. Astronomers expect this X-ray ring will continue to brighten. The outburst is the brightest known supernova in 400 years.

26 **Milky Way bar filled with stars, dust, and gas**

29 **NASA's storm watch**

30 **Mars Express looks into curious crater bulge**

33 **First triple-asteroid system found**

A supernova's colliding winds

Astronomers using the Chandra X-ray Observatory report the long-awaited brightening of SN 1987A's ring has begun. They observed an X-ray ring at the same location as the ultraviolet ring and optical hotspots imaged previously by the Hubble Space Telescope.

SN 1987A, prior to its 1987 explosion, was a blue giant star 20 times the Sun's mass. The star, Sanduleak –69° 202 (SK –69), is roughly 160,000 light-years from Earth, in the Large Magellanic Cloud. SK –69 lived just 10 million years.

In SK –69's final million years, it slowly shed its outer layers. A high-speed wind followed, creating a cavity in the debris. When the star exploded as a supernova, it sent out an ultraviolet (UV) flash that collided with the debris. A ring glowing in UV surrounds SK –69. When the star went supernova, it also sent a shock wave barreling through space. Astronomers have waited for this shock wave to collide with the cavity's edge.

Optical hotspots occur where the shock wave collides with dense pillars of cool gas. This shock wave's hotspots first appeared in 1995 and have increased in number over time. Now the blast wave looks like a string of pearls. The shock-wave collision has heated the gas to millions of degrees. The gas glows brightest in X rays where dense knots meet the supernova's shock front. Astronomers will continue monitoring this collision.

— LIZ KRUESI

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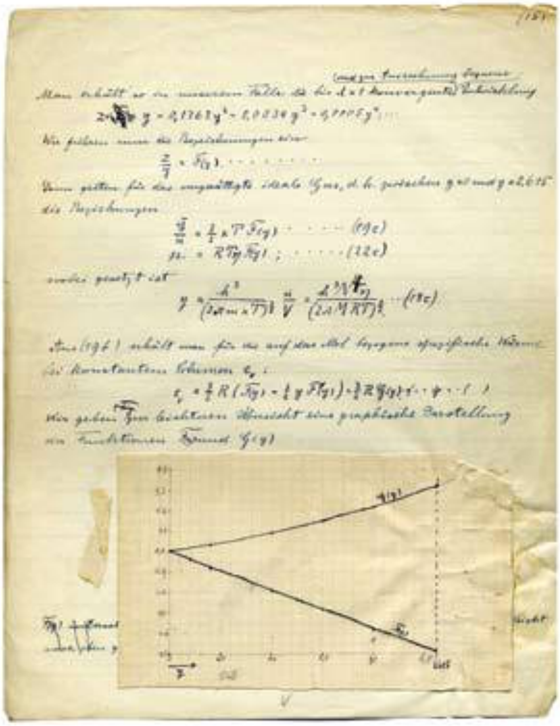
NAME GAME. Asteroid 2004 MN$_4$, which will pass 22,600 miles (36,350 kilometers) from Earth April 13, 2029, is now named 99942 Apophis. Its namesake was a god considered the personification of evil and chaos in ancient Egypt.



UNIVERSITY OF LEIDEN

LOST AND FOUND. A student recovered Einstein's notes on the Einstein-Bose condensate.

Handwritten Einstein manuscript found

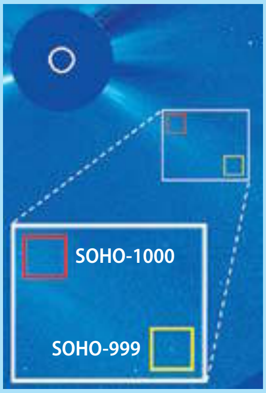
Scholars at Leiden University's Lorentz Institute for Theoretical Physics have discovered a handwritten manuscript of Albert Einstein's last great breakthrough.

The document, dated December 1924, was published the following year. It predicts that particles in a gas clump together and behave as a single atom at temperatures near –459° Fahrenheit (–272° Celsius). Einstein developed the idea in collaboration with Indian physicist Satyendra Nath Bose, and the then-theoretical state of matter was dubbed a Bose-Einstein condensate.

In 1995, Eric Cornell and Carl Wieman of the University of Colorado, Boulder, demonstrated the prediction with rubidium gas, for which they were awarded the 2001 Nobel Prize in physics.

Student Rowdy Boeyink was reviewing documents for a thesis on Paul Ehrenfest, a friend of Einstein, when he came across the manuscript and immediately recognized its importance.

"You can even see Einstein's fingerprints in some places, and it's full of notes and markups from his editor," Carlo Beenakker, a researcher at the institute, told the Associated Press. Images of the paper are available at www.lorentz.leidenuniv.nl/history/Einstein_archive. **— FRANCIS REDDY**



NASA/ESA

MILESTONES. SOHO snagged its 999th and 1,000th comets.

SOHO hits 1,000

The Solar and Heliospheric Observatory (SOHO) is history's most prolific — if unintended — comet-hunter. Amateurs like Toni Scarmato, a high-school teacher from Italy, have found many of the objects by scouring SOHO images over the Internet. Scarmato found SOHO's 999th and 1,000th comets on the same image. **— JEREMY McGOVERN**

Hubble loses a friend

NASA

HUBBLE'S CHAMPION. Astrophysicist John Bahcall (1934–2005) helped bring Hubble to life.

Noted astrophysicist John Bahcall, age 70, died August 17 from a rare blood disorder.

During his 5-decade career, Bahcall was a prominent and active leader of the astrophysics community, publishing more than 500 works and receiving numerous honors. Most recently, he was the Richard Black Professor of Astrophysics at the Institute for Advanced Study in Princeton, New Jersey.

While at the California Institute of Technology in the 1960s, Bahcall theorized neutrinos change flavor. Experiments in the 1990s supported his research.

In the 1970s, Bahcall was a proponent for creating an optical space telescope. Thanks in part to his efforts, the Hubble Space Telescope launched in 1990. Bahcall fought for the endangered space observatory's survival until his death. **— J. M.**

Spitzer maps Milky Way's bar

Our galaxy's center harbors a bar of stars, dust, and gas measuring 28,000 light-years long, according to a team of scientists using Spitzer Space Telescope data. The bar, they say, tips 45° to a line connecting the Sun and the center of the Milky Way, which is twice the angle previous studies determined.

Dust largely hid the structure until Spitzer cut through the haze. Its Galactic Legacy Infrared Mid-Plane Survey Extraordinaire, or GLIMPSE, cataloged some 30 million infrared sources between 10° and 65° of the galaxy's center. The bar reveals itself as an overdensity of red-giant stars on one side of the Milky Way's center.

D. AND C. SMITH/A. BLOCK/NOAO/NSF

LOOK-ALIKE. From a distance, our Milky Way looks like the barred spiral galaxy NGC 1073.

Robert Benjamin of the University of Wisconsin, Whitewater, lead author of the new study, says GLIMPSE observes at wavelengths where the Milky Way is most transparent, giving a clear look at our galaxy's structure. **— F. R.**

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ONE-WAY TRIP. In May 2006, scientists at Switzerland's CERN laboratory will beam muon neutrinos 4r5 miles (732 km) to Italy's Gran Sasso National Laboratory. Some, they hope, will turn into tau neutrinos en route.

NASA's storm watch

NASA

SPIN UP. **NASA's Aqua satellite followed Hurricane Rita's charge through the Gulf of Mexico.**

The winds of change were literal for the agency this summer. On August 29, Hurricane Katrina dealt a glancing blow to New Orleans, flooding the city. The storm damaged the nearby Michoud Assembly Facility, which builds the shuttle's external tanks, and the Stennis Space Center in Mississippi, which tests shuttle engines. A tornado may have hit one Stennis building, but damage and injuries at both facilities were minor.

Then, Hurricane Rita spun toward Houston. As the city evacuated September 21, NASA closed Johnson Space Center. This forced the transfer of the International Space Station's primary flight control to the Russian Mission Control Center in Korolev, outside Moscow. — **F. R.**

Earth spins faster inside than out

Scientists have shown Earth's core spins faster than its surface, proving a long-suspected notion that our planet's interior rotates more like a fluid than a solid. The speed-up, somewhere between 0.3° and 0.5° per year, is small but real.

Xiaodong Song (University of Illinois, Urbana-Chamraign) and Paul Richards (Columbia University's Lamont-Doherty Earth Observatory) presented the first evidence for Earth's fluid-like, or differential, rotation in 1996. But some seismologists weren't convinced.

The new study by Song, Richards, and colleagues (*Science*, August 26, 2005), ends this debate. "The only plausible explanation is a motion of the inner core," Song claims.

Earth's iron core consists of two layers: a solid inner core about 1,500 miles (2,4[illegible]0 kilometers) across and a fluid outer core about 4,350 miles (h,000 km) wide.

The team compared 17 sets of similar seismic waves — called waveform doublets — from historical earthquakes that traversed Earth's fluid and solid cores during the last 35 years. The doublets allowed the scientists to detect time delays experienced by the waves as they passed through Earth. These delays provide compelling evidence for differential rotation of the solid inner core.

An electromagnetic twist created by the dynamo in the outer core may force the inner core to spin relative to Earth's mantle and crust, Song says.

The fluid outer core creates little frictional drag, insulating the solid inner core from the motion of Earth's mantle. — **F. R.**

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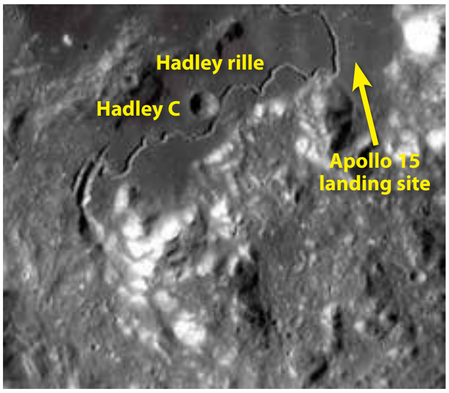
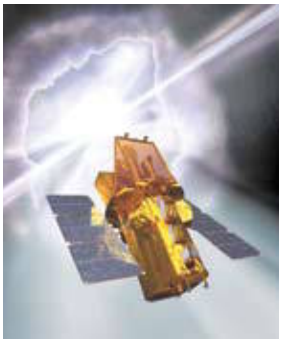


ESA

Lunar landing site

FREEFORM. **Small Missions for Advanced Research in Technology 1 (SMART-1) shot Hadley rille, an ancient lava channel that snakes 75 miles across the Moon's Palus Putredinis (Marsh of Decay). In 1971, Apollo 15 astronauts David Scott and James Irwin landed near the rille's northeastern part. The European Space Agency's SMART-1 spacecraft imaged the area from a height of 1,240 miles (Apollo 15 relics are not visible). — F. R.**

Swiftly refining GRBs



D. ARMBRECHT (SPECTRUM ASTRO)/NASA

SWIFT LEARNER. **NASA's Swift satellite observes, on average, one gamma-ray burst every few days.**

Using NASA's Swift satellite, astrophysicists observed a never-before-seen transition stage between a gamma-ray burst's (GRB) initial emission and its X-ray afterglow. A newly observed X-ray signal falls off with unexpected speed before the previously known afterglow begins. Neither observation fits current GRB models.

Long-duration GRBs radiate energy in two stages — a prompt gamma-ray emission followed by a lower-energy afterglow. The prompt emission lasts more than 2 seconds and is the result of internal shocks. The afterglow can last months and is the result of the GRB's material colliding with surrounding material.

Scientists using pre-Swift instruments had observed only one afterglow stage. Now, a team led by Gianpiero Tagliaferri of Brera Observatory in Merate, Italy, has found two stages (*Nature*, August 18, 2005).

The researchers' data agree with aspects of current GRB models: The gamma-ray emission is an internal effect, while the afterglow is external. But the team isn't sure why the early X-ray emissions show such a steep decline. Observations of this transition-phase can help astronomers determine the properties of what initiates GRBs, which is still an astronomical riddle. **— L. K.**

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The Cocoon Nebula (IC 5146). Image by Mark Sibole using his Meade 10" LX200 and a Meade f/3.3 focal reducer. Meade DSI Pro, LUM=60 min., Ha=120 min., RGB=40 min./channel. Autoguided with DSI camera.

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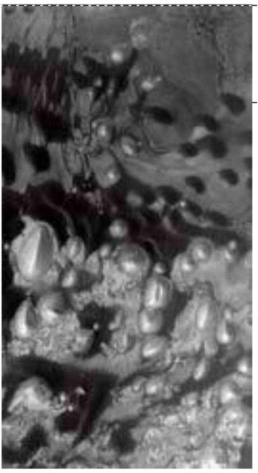
30-05165.

SOLAR WHOPPER. On September 7, an X17 flare — the fifth largest on record — erupted from the Sun.



NASA/JPL/MSSS IMAGE MOC2-1190

Kaleidoscope landscape

MIX IT UP. Martian sediments come in two basic forms: light-toned outcrops of layered rock, and dark, windblown dunes. The layered rocks seen here, found on the floor of a crater in Arabia Terra (8.9° N, 1.2° W), once extended across the entire scene. The dark dune sand is likely composed of grains rich in iron-, magnesium-, aluminum-, and silicon-bearing minerals. This Mars Global Surveyor image spans about 1.9 miles (3 km). — F. R.

Mars Express: Nicholson Crater's central mystery

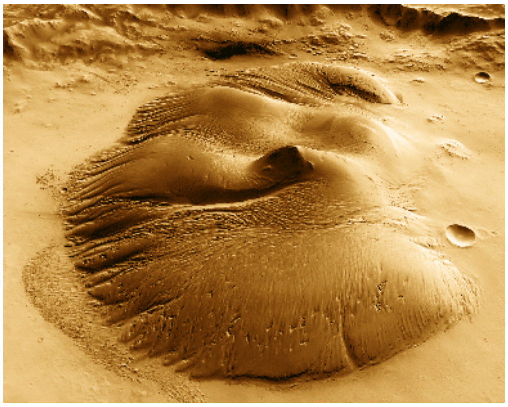
It seems paradoxical, but large impact craters always have mountainous peaks at their centers. Nicholson Crater, located at the southern edge of Mars' Amazonis Planitia, is no exception. At the center of the 62-mile-wide (100 kilometers) crater, a 2.2-mile-high (3.5 km) mountain rises nearly to the crater's rim. Central peaks form because rock rebounds after being compressed in an asteroid or comet impact — imagine a slow-motion replay of a raindrop splashing into a puddle.

But there's something odd about Nicholson's central mountain. It forms the apex of a bulge that nearly spans the crater and covers much of its floor. Usually, erosion grinds down a crater's central peak, often erasing it completely. But, sometimes wind and water can deposit more material than they take away.

That's what seems to have happened at Nicholson Crater, but planetary scientists can't figure out how. If water once flowed into and filled the crater, settling sediments could have formed the bulge — but there's no dried-up channel leading into the crater.

Perhaps the crater's rebound formed hydrothermal vents and springs that subsequently piled debris into its center. Trouble is, such features aren't usually associated with the movement of much material on Earth.

New images from the European Space Agency's Mars Express spacecraft reveal rilles, gullies, and channels on the bulge. These features suggest water once drained from the top of the structure after it was in place. For now, though, the origin of Nicholson Crater's bulge remains another martian mystery. — **F. R.**



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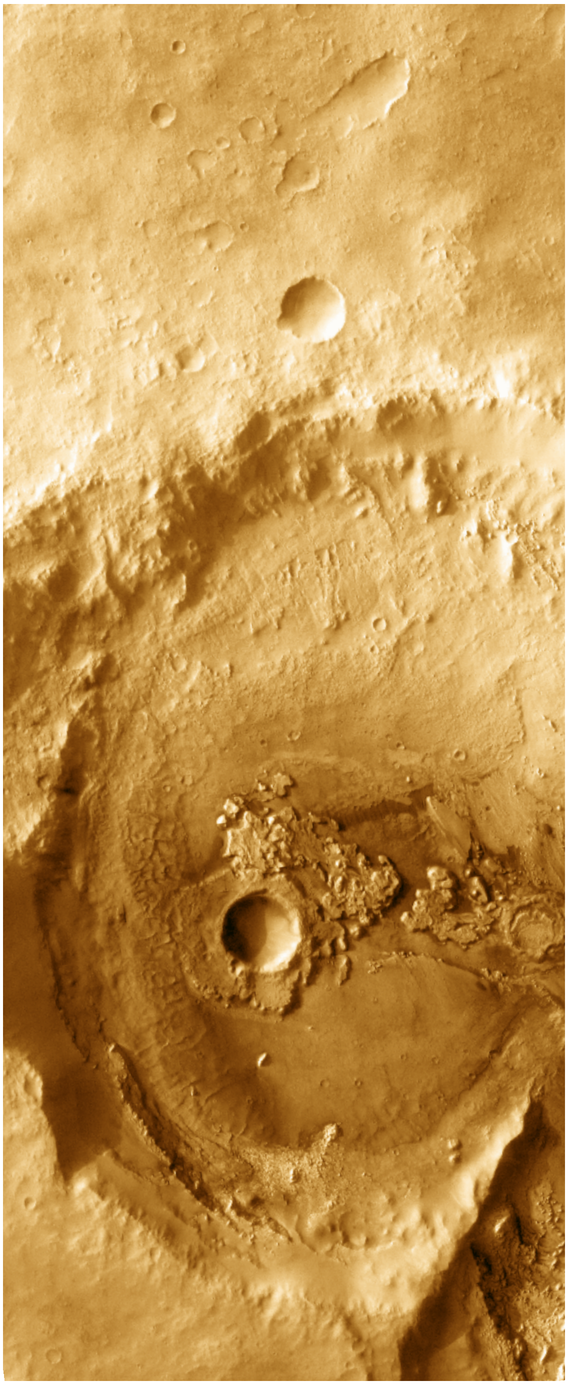
SCULPTED PEAK. This perspective view, created from Mars Express imagery, features Nicholson Crater's curious bulge.



NASA/JPL/ASU IMAGE 20050720A

Mars Odyssey: Geological tangle in Meridiani

COLLECTION POINT. In northern Meridiani on Mars, this unnamed crater (26 miles, or 37 km, wide) has accumulated sand dunes, a thick mantle of dust, and small craters on its floor, all while suffering wind erosion. This visual-wavelength Thermal Emission Imaging System image spans about 16 miles (26 km). — ROBERT BURNHAM

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Prospects improve for Hubble repair

The prospects for a rescue mission to the faltering Hubble Space Telescope (HST) seem to be brightening.

Although NASA will not formally approve a repair mission until after the next shuttle flight, expected around spring 2006, HST project managers intend to be ready to launch the servicing mission by December 2007.

The repair job involves installing fresh batteries, gyroscopes, and other new instruments. If the mission is successful, planners expect HST to last through at least 2012.

Although the current batteries may wear out by 2008, they tend to fail gracefully. This will allow HST to maintain an adequate posture to protect it from excess heat or cold — even if it loses the ability to point accurately enough for science observations.

A rescue mission must reach HST before its equipment degrades so far that it loses this pointing control and goes electrically dead.

At that point, the thermal stresses of a random tumble through sunlight and shadow would inflict permanent distortions on HST's high-precision optical alignments, so a subsequent rescue mission would find it only a useless hulk.

A new control technique — implemented in September — decreases this threat and extends the telescope's expected lifetime into 2008.

Before the change, HST used three gyroscopes. The new technique — which uses HST's Fine Guidance Sensors to fill in the missing data normally generated by the third gyro — lets the telescope function fine on two.

This preserves two more gyroscopes as spares, for use when the operating ones inevitably wear out.

"Hubble science on two gyros will be indistinguishable from the superb science we have become accustomed to over the years," says senior Hubble scientist David Leckrone.

NASA

LIFE SUPPORT. Astronauts left Hubble with six new gyroscopes in 1999. Two have failed, and one has been shut down. Scientists hope a new technique relying on just two gyros will help extend the telescope's science until at least mid-2008.

Sometime before NASA finally loses control over the telescope, the space agency will need to install a propulsion package for the controlled de-orbit.

But by deferring that hardware from the upcoming repair mission — a decision made in August — NASA has not only saved $132 million (not counting the shuttle flight), it has also made the mission safer.

By adding some rendezvous and docking sensors to HST, NASA will make a later robotic docking mission much easier. This post-2010 mission would carry the propulsion module, launched on an expendable booster.

Depending on the progress of replacement payloads, such as the James Webb Space Telescope (currently scheduled for launch in 2011), the robotic docking might also carry new batteries and gyroscopes to Hubble. This equipment could take over for, by then, faltering hardware, possibly extending the space telescope's life even longer.

— JAMES OBERG

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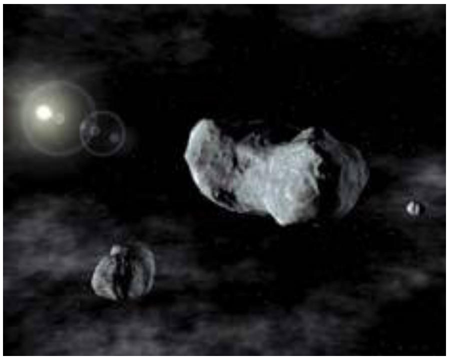
ESO

FAMILY OF THREE. Sylvia and her two moons, Romulus and Remus, comprise the first triple asteroid discovered.

Asteroid times 3

Not one, but two small moons, accompany asteroid 87 Sylvia, which makes the space rock the first known triple-asteroid system.

"People have been looking for multiple asteroid systems for a long time," says Franck Marchis, the University of California astronomer who discovered the second moon. "I couldn't believe we found one." Marchis and his colleagues made the discovery using one of the European Southern Observatory's 8-meter telescopes in Chile.

Sylvia was discovered in 1866 and resides in the main asteroid belt, between the orbits of Mars and Jupiter. Named for Rhea Sylvia, the mythological mother of the founders of Rome, the asteroid's moons have been named for her twin children: Romulus and Remus.

Sylvia measures about 235 by 160 by 145 miles (380 by 260 by 230 km) and resembles a lumpy potato.

Newfound Remus measures just 4 miles (7 km) across and orbits Sylvia at a distance of 441 miles (710 km). Romulus, 11 miles (18 km) wide, lies 845 miles (1,360 km) from Sylvia. Both moons orbit in the same plane and direction.

When two asteroids collide and merge, chunks of debris may settle into orbits around the larger bodies as moons. Some 60 asteroids are known to have a satellite. Sylvia joined the group when its first moon was found in 2001.

The team's results appeared in the August 11 issue of the journal *Nature*.

— LAURA BAIRD

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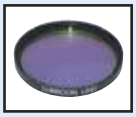

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It is certainly entertaining, often funny, even awe-inspiring at times, as befits the subject matter. But clear introductions to essential principles of physics abound throughout these lectures, including density, quantum theory, gravity, and even the General Theory of Relativity. And Dr. Tyson also includes forays into disciplines such as chemistry and biology as needed to explain events.

Saturn.

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For example, Dr. Tyson begins one lecture at a point 13 billion years ago, when all space, matter, and energy in the known universe were contained in a volume less than one-trillionth the size of a pinpoint—about the size of an atom. By the time he finishes, the cosmos has been stretched, the planets and Earth formed, and 70 percent of Earth species wiped out by a gigantic asteroid—clearing the way for the evolution of humanity.

As Dr. Tyson notes, we are made of stardust, just as the planets are. And he has created a course that explains exactly how that came to be, beginning with a grounding in the basic "machinery" of matter, forces, and energy which reveals itself throughout the universe.

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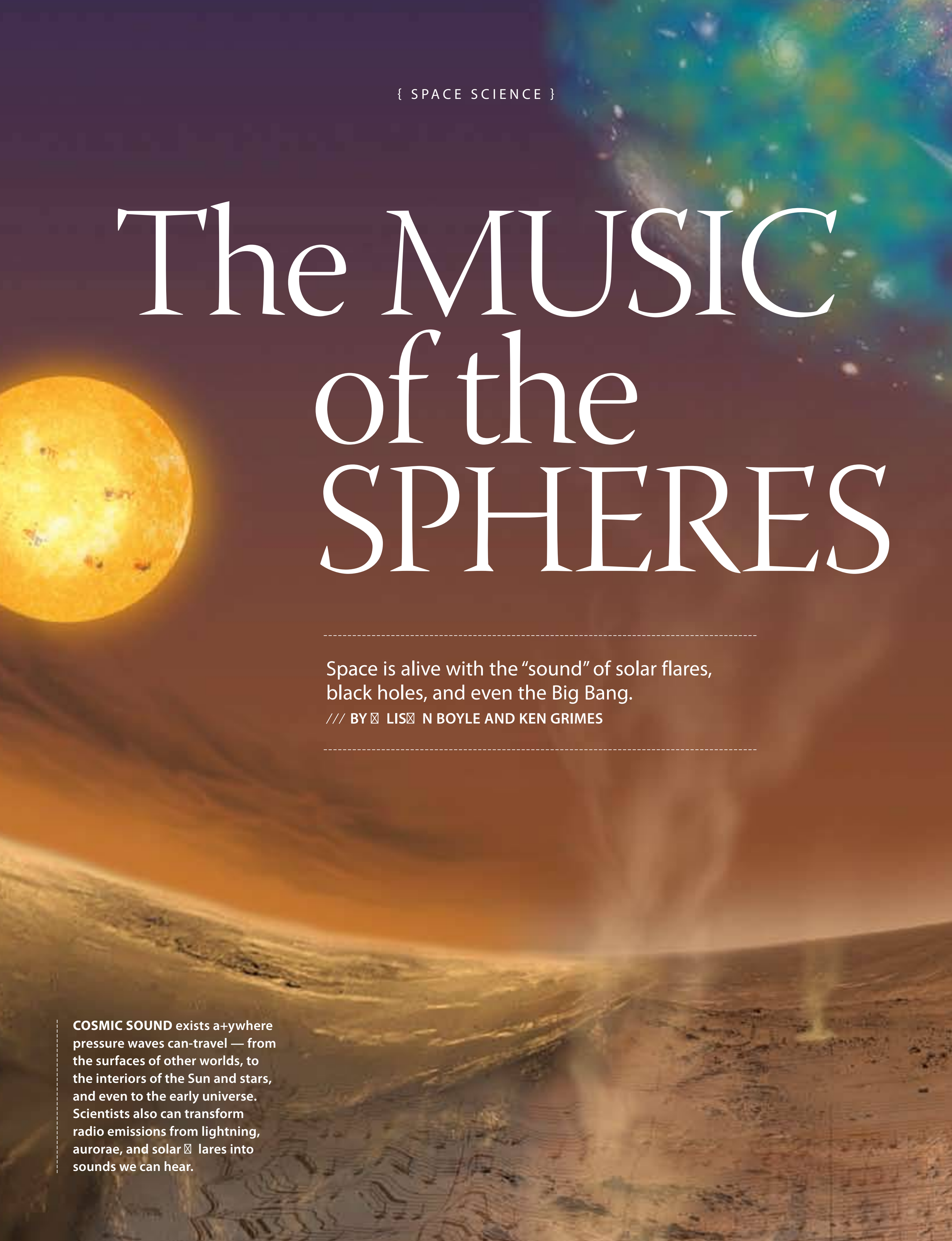


{ SPACE SCIENCE }

The MUSIC of the SPHERES

Space is alive with the “sound” of solar flares, black holes, and even the Big Bang.

/// BY ALISON BOYLE AND KEN GRIMES

COSMIC SOUND exists anywhere pressure waves can-travel — from the surfaces of other worlds, to the interiors of the Sun and stars, and even to the early universe. Scientists also can transform radio emissions from lightning, aurorae, and solar flares into sounds we can hear.

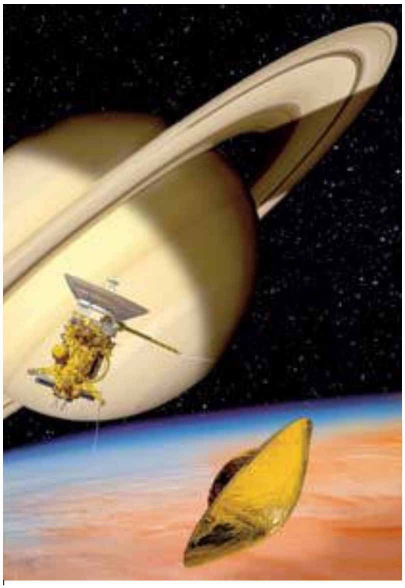
MICHAEL CARROLL FOR *ASTRONOMY*

A storm approaches. A wind gust hums through the vehicle's instrument booms. As it subsides, a rumble of distant thunder rolls across the barren landscape, and raindrops drum lightly on the craft's metal hull.

But this isn't a spring shower on Earth. The vehicle is a robot lander investigating the stormy southern pole of Saturn's moon Titan, some 750 million miles (1.2 billion kilometers) away. And the rainfall isn't water: It's frigid liquid methane.

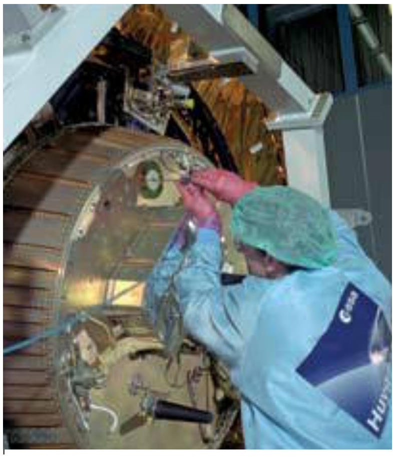
Titan may offer us the best chance for hearing an alien cloudburst, but any planet with an atmosphere provides audio opportunities. Although sight and sound are the two dominant ways we explore our environment, scientists have been reluctant to place microphones on planetary missions. No one questions the wisdom of cameras on spacecraft exploring other worlds, but the scientific value of a microphone seems less clear. Yet sound is powerfully evocative.

Moreover, sound exists anywhere pressure waves can travel. Sound waves not only course through the atmospheres of Mars, Venus, and Titan, but they also echo inside our Sun and ripple through the gas surrounding an accreting black hole. Other cosmic "sounds" occur when electrically charged gases, such as those in solar flares and aurorae, interact with a planet's magnetic field. The result: radio waves scientists can translate into sounds we can hear.



ESA

THE HUYGENS PROBE (bottom) set the record for the most distant audio broadcast January 14, 2005, when it recorded the sound of its descent through Titan's atmosphere.



ESA

BEFORE HUYGENS left Earth, European Space Agency engineers attached to it a CD-ROM containing signatures, messages, and drawings from more than 80,000 people. Four pop songs, composed by French musicians Julien Civange and Louis Haéri as part of the Music2Titan project, also made the trip.

Huygens' coda

This year brought us the farthest audio broadcast from another world. On January 14, 2005, the European Space Agency's Huygens probe, which hitched a ride to Saturn on NASA's Cassini spacecraft, successfully landed on the planet's largest moon, Titan. It was the most distant landing ever attempted. Microphones on Huygens recorded its hours-long descent through Titan's atmosphere and its stay on the surface — an acoustic first.

"The sonic package on Huygens included sonar instruments to map local surface contours, much as bats map their terrain in pitch dark," says John Zarnecki, principal investigator of the Huygens surface package. He's particularly excited about the possibility that, during descent, the probe's acoustic sensors picked up evidence of methane droplets. "We haven't finished

/// MIKE WAITS FOR A LIFT

ASA/JPL/CORNELL

DUST DEVILS SWIRL in Mars' Gusev Crater. On March 9, 2005, one of them swept over Mars Exploration Rover Spirit, whisking the vehicle's solar panels clean and boosting its power. We might have heard it if Spirit had carried a microphone.

A MICROPHONE FOR MARS COULD BRING FAT OUT SOUND?

Mars seems an obvious candidate for sound studies. At the surface, the planet's carbon dioxide atmosphere is less than 1 percent as dense as Earth's. Yet the Red Planet produces winds strong enough to shift clouds, sculpt sand dunes, create whirlwinds, and loft dust to high altitudes in global storms.

"There are certainly processes occurring in the martian atmosphere that will generate audible sound," says John Zarnecki of Britain's Open University. He thinks planetary sounds have a rich science potential. "An acoustic instrument package dropped onto Mars could give us valuable information about processes like local wind speeds," he says. "A series of such packages could allow us to test theories about global weather patterns."

Experiments show sounds on Mars can be detected by existing microphone technology. The Planetary Society, a non-profit space-advocacy group, teamed up with the Space Sciences Laboratory at the University of California, Berkeley, to create a small, lightweight, low-cost microphone for NASA's Mars Polar Lander mission. The microphone itself is similar to those used in hearing aids.

The experiment rode to Mars in 1999, but the lander crashed as it descended to the surface. The French space agency CNES picked up on the project and planned to integrate two mikes into each camera head on its four Netlander spacecraft, slated to reach Mars in 2007. But the mission was cancelled, and the Mars Microphone has yet to fly.

Zarnecki looks beyond this simple experiment to full acoustic packages designed to monitor long-wavelength, low-frequency infrasound. On Earth, scientists are completing a global network of infrasound facilities to listen for clandestine nuclear blasts. Some stations already have picked up large meteoroids exploding high in our atmosphere. A similar network on Mars could measure the frequency and intensity of meteorite impacts there.

— A. B. and K. G.

processing the raw data yet, but there are tantalizing suggestions that we've caught the first-ever sounds of alien rain."

Acoustic technologies are well suited for use in exploring worlds like Titan and Venus, where thick atmospheres hamper visual investigation. Sound waves travel faster in denser atmospheres, so a given sound will go farther.

Vibrating Sun

Our star is an enormous ball of hydrogen and helium — and a medium capable of transmitting sound waves. In the 1960s, astronomers noticed absorption lines in the Sun's spectrum change position slightly over a period of about 5 minutes. Absorption lines change position because gas is rising and falling, moving toward us and away from us, creating Doppler shifts. In 1970, Roger Ulrich at the University of California, Los Angeles, suggested the solar surface was responding to sound waves trapped within the Sun.

Sounds travel as pressure waves. In the Sun, these waves travel to the surface, reflect off it, and then travel back toward the core. As the waves interact with one another, the Sun vibrates in millions of different frequencies and surface patterns. Astronomers have mapped in detail more than 100,000 oscillation modes — think of each as a single musical note. The Sun's dominant frequency is 3 millihertz, which means a given sound wave crests about every 5 minutes.

"What appliance can pierce through the outer layers of a star and test conditions within?" asked Sir Arthur Eddington, the famous British astronomer, in his 1926 book *The Internal Constitution of the Stars.* The discovery of solar oscillations paved the way for astronomers to peer inside the Sun and other stars. Each oscillation mode penetrates to different depths. So by mapping each in detail, astronomers can test predictions from models of the Sun's interior in much the same way seismologists use earthquake vibrations to "look" inside Earth. Using this technique, called helioseismology, astronomers have recorded vibrations in other stars, too, including Beta Hydri, Alpha Centauri A and B, Procyon, and Xi Hydrae. Such studies provide new insights into stellar size, density, temperature, age, structure, and composition.

Solar-system soundscape

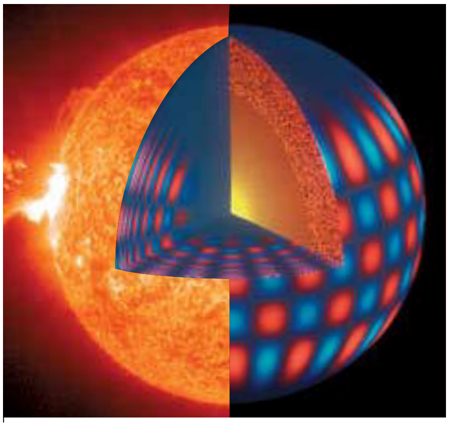
In interplanetary space, there's no medium to carry acoustic waves, so in the most literal sense, there is no sound. But, says Don Gurnett, head of the University of Iowa's Space Plasma Wave Research Group, there are other kinds of waves. "The main thing that most people don't realize is that space is not actually a vacuum. There is a substantial gas pressure everywhere between the planets." This gas consists of electrically charged ions and electrons — what scientists call plasma.

Gurnett has tuned into interplanetary plasma and says it's far from quiet. "Waves propagate in this gas, and there is an astonishing variety of plasma waves," he explains. "On Earth, we essentially just have waves for sound and light, but in the plasma, you get more exotic effects due to things like magnetic fields and rotating electrons."

The Iowa group eavesdrops on plasma with surprisingly modest equipment — essentially, a radio receiver. Plasma waves are pressure fluctuations mainly occurring at frequencies between 20 and 20,000 hertz — the same range as human hearing. For plasma waves beyond the audio range, Gurnett's team transposes the signals to frequencies humans can hear.

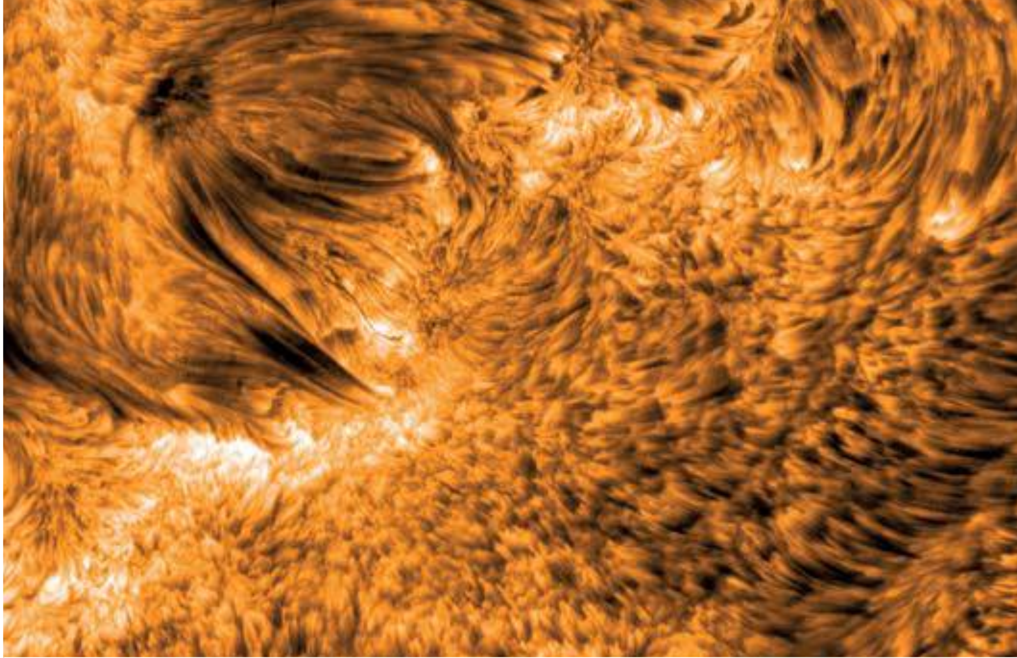
The resulting sounds are otherworldly. Sometimes, they're vaguely reminiscent of

Alison Boyle and **Ken Grimes** *are science writers based in London.*



SOHO AND NSO/AURA/NSF

SOUND WAVES TRAPPED beneath the solar surface make the Sun vibrate in nearly 10 million different modes; this diagram illustrates one of them. Regions of the Sun's surface rising are shown as light blue; receding areas are red. By measuring the frequencies of many modes and comparing them to theoretical models, astronomers can infer much about the Sun's internal structure.



SST

A CARPET of short, dark jets called spicules rushes from the Sun's surface. These jets result from sound waves that leak out of the Sun's interior through a zone near the surface. They blast gas into the Sun's lower atmosphere at speeds up to 30,000 miles per hour (48,000 km/h). The Swedish 1-meter Solar Telescope on the island of La Palma, Spain, captured this image June 16, 2003.

underwater whale-song recordings. At other times, they resemble the "electronic tonalities" that served as musical scores in movies like 1956's *Forbidden Planet*.

The first plasma "sounds," called whistlers, were discovered during World War I. They occur as sporadic falling tones in the background of Very Low Frequency (VLF) radio transmissions. Later, in 1953, Owen Storey at England's University of Cambridge showed whistlers result from lightning-generated radio waves rising into plasma above Earth's atmosphere. Plasma waves bounce back and forth between the Northern and Southern hemispheres along Earth's magnetic field lines. High-frequency plasma waves travel faster than those of low frequency, creating a whistler's distinctive tune. "Whistler signals can give us interesting information about the density of plasma around Earth," says Gurnett.

They can also tell us about lightning on other worlds. Gurnett and his team, who work with the Radio and Plasma Wave Science (RPWS) experiment aboard the Cassini spacecraft, detected Saturn's lightning from 100 million miles (161 million km) away. The same instrument didn't sense terrestrial lightning from more than 55,000 miles (89,000 km) away. "This means that radio signals from Saturn's lightning are on the order of one million times stronger than Earth's lightning," Gurnett explains. "That's just astonishing to me!"

The northern lights, the nickname for aurorae, are plasma, too, and they have songs of their own. Aurorae occur when energetic electrons stream into Earth's atmosphere. Gurnett's investigations show these impacting electrons also produce intense radio emissions in the 100 to 500 kilohertz range. Similar emissions occur on Jupiter, Saturn, Uranus, and Neptune, telling scientists that processes similar to Earth's aurorae also occur on these planets.

Pulsar bongos

A spinning neutron star is the crushed remnant of a star that has collapsed and exploded. Due to intense magnetic fields, these objects beam radiation from their magnetic poles. If a pole of one of these neutron stars happens to sweep past Earth, astronomers detect regular pulses of light and radio waves. These objects, called pulsars, pulse so regularly that they're the cosmos' most accurate clocks.

Giant radio telescopes like the 76-meter Lovell dish at the Jodrell Bank Observatory in Manchester, England, capture pulsars' ticks. Jodrell Bank scientist Michael Kramer says astronomers usually analyze pulsars by clocking pulse arrival times. But he thinks it's instructive to listen to how regular the pulses are.

So what does a pulsar sound like? The Vela pulsar, born out of a supernova about 10,000 years ago, sweeps its beam past us

SOUND SENSE

ACOUSTICS
The study of sound, including its production, transmission, and effects

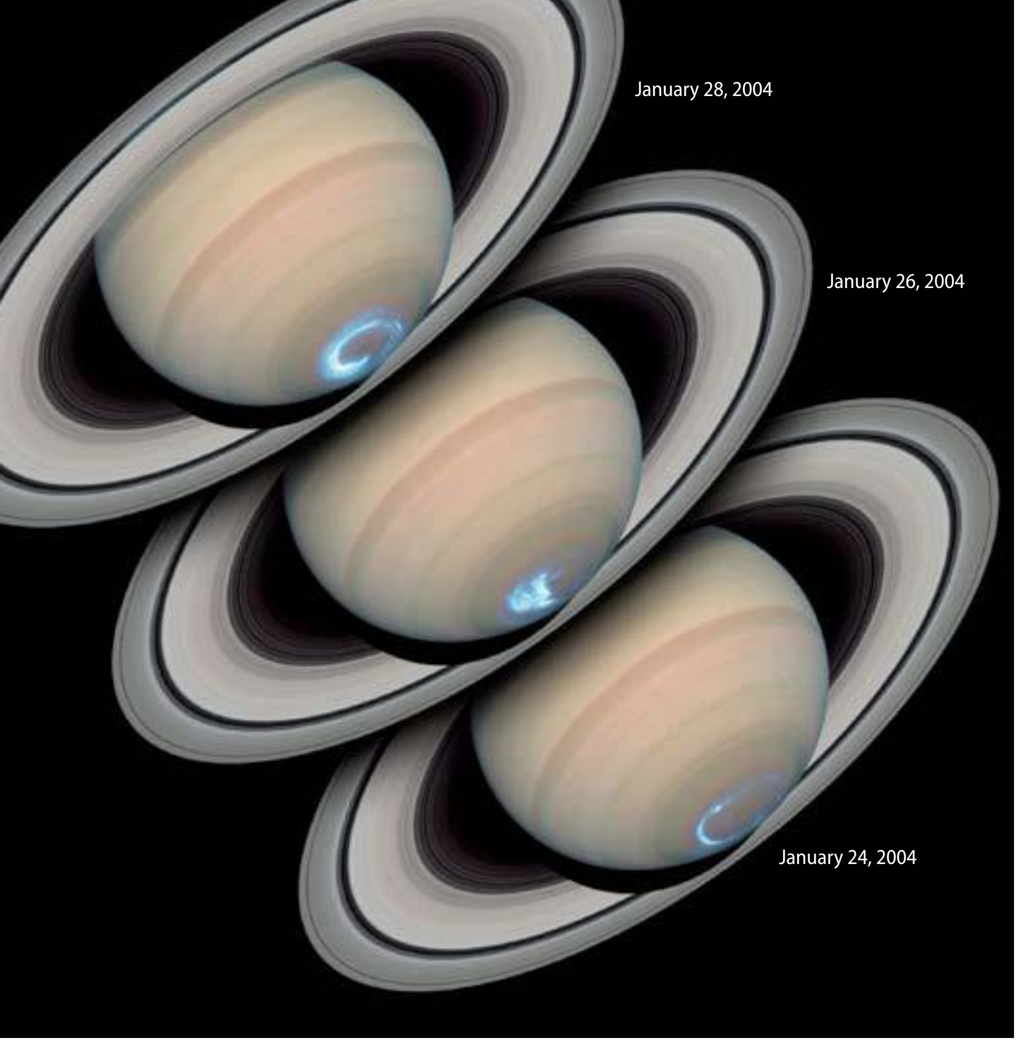
FREQUENCY
The number of complete waves that pass a given point in a given time — usually measured in hertz (Hz; 1 Hz = 1 cycle per second)

INFRASOUND
Sound waves with frequencies below 20 hertz, the lower limit of human hearing

OCTAVE
The span of frequencies between one musical note and another with exactly twice the frequency. Middle A on a piano has a frequency of 440 Hz. The next higher A is one octave up, at a frequency of 880 Hz.

PITCH
The perceived frequency of a tone on a scale from low to high

WAVELENGTH
The distance a wave travels in the time it takes to complete one cycle



NASA/ESA/J. CLARKE (BOSTON UNIVERSITY), Z. LEVAY (STScI)

THE HUBBLE SPACE TELESCOPE captured Saturn's lively southern aurorae in January 2004. Like terrestrial aurorae, electrons streaming toward the planet's magnetic poles create the ring of dancing light. They also produce radio emissions Cassini scientists have detected and converted into eerie sounds humans can hear.

11 times a second. Kramer says it sounds "like a bongo player in the sky."

Black-hole basso profundo

In 2002, NASA's Chandra X-ray Observatory found a black hole in the Perseus Galaxy Cluster sounding the deepest cosmic note. "It's not the kind of thing you could listen to," says Andy Fabian of the University of Cambridge. "But the intensity isn't so different from that of the human voice."

Astronomers don't actually hear this note — they see it. The cluster lies some 250 million light-years away, and Chandra detects the X-ray glow of hot gas between the cluster's galaxies. Fabian and his team have found ripples caused by pressure changes. "It's like looking at ripples on a pond," he explains. "You can't feel the waves if you're not in the pond, but you can tell they're there by looking at the ripples."

Fabian estimates the black hole's mass to be about a billion times that of our Sun. Jets of hot, high-speed plasma near the hole's event horizon squirt out along its spin axis, forming cavities in the surrounding gas. The ripples around the cavity are spaced so evenly, the scientists think the black hole creates a new pressure wave regularly — about once every 10 million years. This frequency corresponds to a musical B-flat about 57 octaves — eight full keyboards — below a piano's middle B. That's a million billion times below human hearing's limit.

The finding could solve a long-standing cosmic mystery. Current theories predict intracluster gas should cool enough over time to form millions of stars. But astronomers don't see this happening, and sound waves might be a mechanism that keeps the gas hot. Fabian and his team say that to offset the predicted cooling, the black hole must have been blaring almost constantly for the past 2.5 billion years.

Chandra has since detected sound waves from a black hole in the Virgo Galaxy Cluster, and astronomers see hints of similar activity elsewhere.

Big Bang concerto

The University of Virginia's Mark Whittle has been looking at ripples caused by sound waves from even further back in time — almost, in fact, from the universe's very beginning. Imprinted in the cosmic microwave background (CMB) is the Big Bang's acoustic signature.

In the universe's first 380,000 years, it was too hot for atoms to form — electrons and protons moved about freely. This fog of subatomic particles continually scattered light, making the early universe opaque. Light escaped only when things cooled down enough for atoms to form. What we see in the CMB is enormously stretched (redshifted) light emitted when the universe first became transparent. As light escaped, it imprinted a subtle light-and-dark pattern on the CMB.

This imprint offers to tell cosmologists a great deal about the young universe at this important instant. NASA's Wilkinson Microwave Anisotropy Probe (WMAP) has mapped the bright and dark patches at the smallest scales. These patches correspond, more or less directly, to the peaks and troughs of pressure fluctuations — sound waves moving through the early universe. "One can actually see primordial sound waves ... frozen in place ... as the universe turned transparent," Whittle explains. He likens it to viewing a snapshot of the ocean, where a variety of waves are superposed on one another.

Using WMAP data and a computer, Whittle and his colleagues have analyzed these waves to decipher the relative loudness of high and low notes. The upper octaves of the CMB's acoustic spectrum show many of the features of a vibrating object: a strong fundamental tone with a wavelength of 220,000 light-years and a sequence of higher harmonics at shorter wavelengths. This analysis forms the basis of Whittle's re-creation of sound in the early universe.

Such long sound waves equate to a pitch about 50 octaves too low for the human ear to hear, so Whittle has boosted the signals upward by this amount. Now, human ears can catch the roar of a youthful universe. "There's lots of power in the low tones. Some can move your tummy rather than your ear drums, a bit like the deepest

/// THE PYTHAGOREANS

Best known today for proving the geometry theorem that bears his name, Pythagoras of Samos (ca. 560–480 B.C.) was a philosopher intrigued by whole numbers — so much so, he considered them to be a kind of fundamental cosmic element. He founded a school at the Greek colony of Croton, in southern Italy, but he left no writing of his own. Most of his work blurs into that of his followers.

Pythagoras played the lyre and, at some point, observed that a plucked string produces its most pleasing tones when divided into whole-number ratios. For example, a string held at its middle produces sound pitched exactly one octave higher than the whole string.

This hidden order in sound reinforced his sense of an underlying cosmic harmony expressed in number and proportion. His followers extended this idea, assuming that the crystalline spheres thought to carry the Sun, Moon, and planets were spaced according to musical intervals. Later, Plato imagined each sphere producing a single tone, and "the music of the spheres" was born.

Twenty centuries later, these ideas resonated in the mind of German mathematician and astronomer Johannes Kepler. "I grant you that no sounds are given forth," he wrote in *Harmonice Munde* (1619), "but I affirm ... the movements of the planets are modulated according to harmonic proportions."

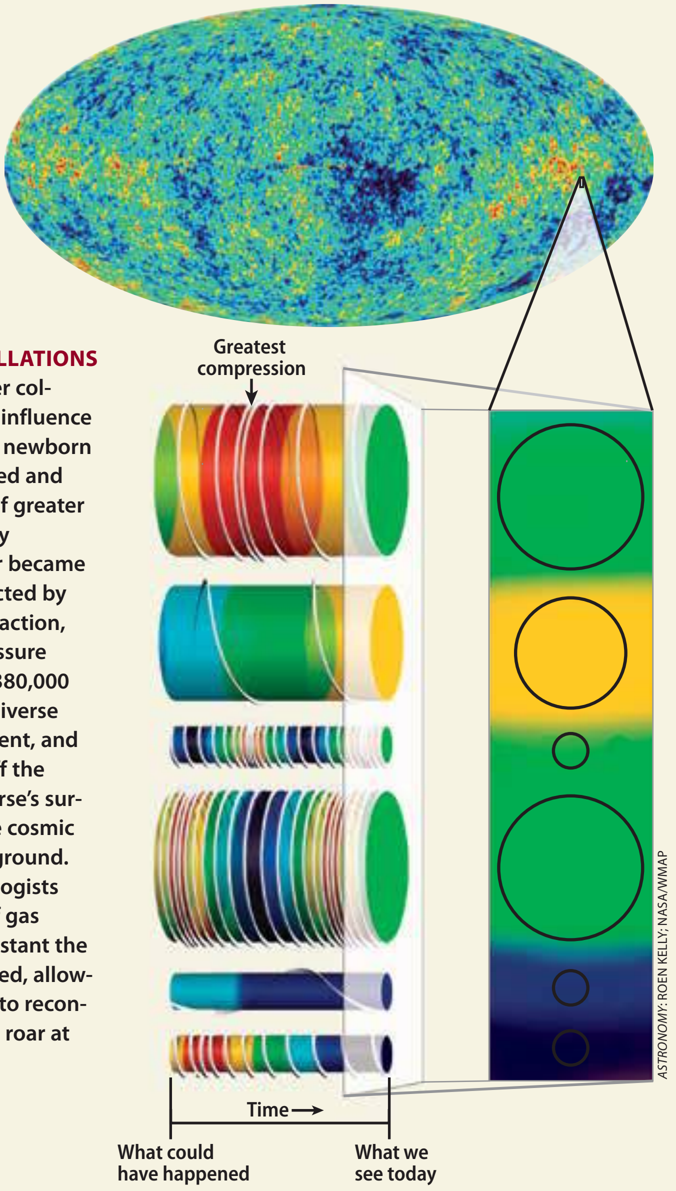
Ultimately, Kepler realized he couldn't make such a system work. But, eventually, he did determine the mathematical relationships governing planetary motion.

Pythagoras would have been proud.

— *Francis Reddy*

Cosmic birth cry

ACOUSTIC OSCILLATIONS arise when matter collapses under the influence of gravity. As the newborn universe expanded and cooled, regions of greater and lesser density appeared. Matter became increasingly affected by gravitational attraction, which set up pressure changes. About 380,000 years ago, the universe became transparent, and light scattered off the expanding universe's surface, creating the cosmic microwave background. This gave cosmologists a freeze-frame of gas motions at the instant the scattering occurred, allowing astronomers to reconstruct the cosmic roar at that moment.



ASTRONOMY: ROEN KELLY; NASA/WMAP

notes of a cathedral organ," he says. And it's loud. When the cosmic fog cleared and the CMB was put in place, pressure variations were the equivalent of 110 decibels — "about what you'd get in the front row of a Pink Floyd concert."

Whittle used computer models to simulate cosmic structure before the CMB formed, and then generated acoustic data. So what did the Big Bang sound like? Initially, Whittle explains, it was silent. The beginning expansion was so pure that pressure waves simply didn't exist. But the distribution of matter was lumpy, and denser regions gradually attracted hot gas toward them. Infalling gas created pressure waves that set up powerful oscillations, driving gas into and out of gravitational valleys. "As time passed, this gas had longer to fall into ever larger valleys, making bigger sound waves," he says. So, as the universe expanded, its pitch dropped while its volume simultaneously grew louder.

"There's a moment of silence, then a descending scream that grows in volume," he explains. This sound settles into a roar that lasts until light floods the universe. Then, the cosmic pressure drops by a billion times, and hot gas settles into gravitational valleys created by dark matter. As the sound waves die out, galaxies start to form. The universe as we know it has begun.

Whittle admits that listening to the sounds of the Big Bang is unlikely to reveal any new scientific information, but he feels producing these sounds is a useful educational tool. "There's a powerful emotional response to these sounds," he says. Cosmologists are excited about exploring the CMB's details, and Whittle's sounds give non-scientists a sense of what their excitement is all about.

As planetary scientists, astronomers, and cosmologists tune in to the "sounds" of space, they're gaining new insights about the way the universe works. A kind of cosmic symphony is playing all around us. What better term for it than the music of the spheres, even if it's not what ancient Greek philosophers once imagined? **A**

ONLINE EXTRA To hear the sounds of space discussed in this article, tune in to www.astronomy/com/toc

{ COSMOLOGY }

In search of the first

Detecting the earliest stars will help astronomers unlock secrets of the infant universe. /// BY RAY JAYAWARDHANA

Looking up at the star-studded sky on a clear night, it's difficult to imagine there was a time when the universe contained no stars, no galaxies, no shining celestial bodies of any kind. Yet, for a significant stretch of the first roughly 10 million years after the Big Bang, total darkness permeated the cosmos.

Then came the first generation of stars, the brilliant and short-lived ancestors of our Sun and its kind, which burnt through the dense fog of primordial hydrogen and helium atoms. Investigating how these first stars ushered in the cosmic dawn and made possible all else that followed — including human life on Earth some 14 billion years later — is one of the hottest research frontiers in cosmology today.

Hiding in the first billion years

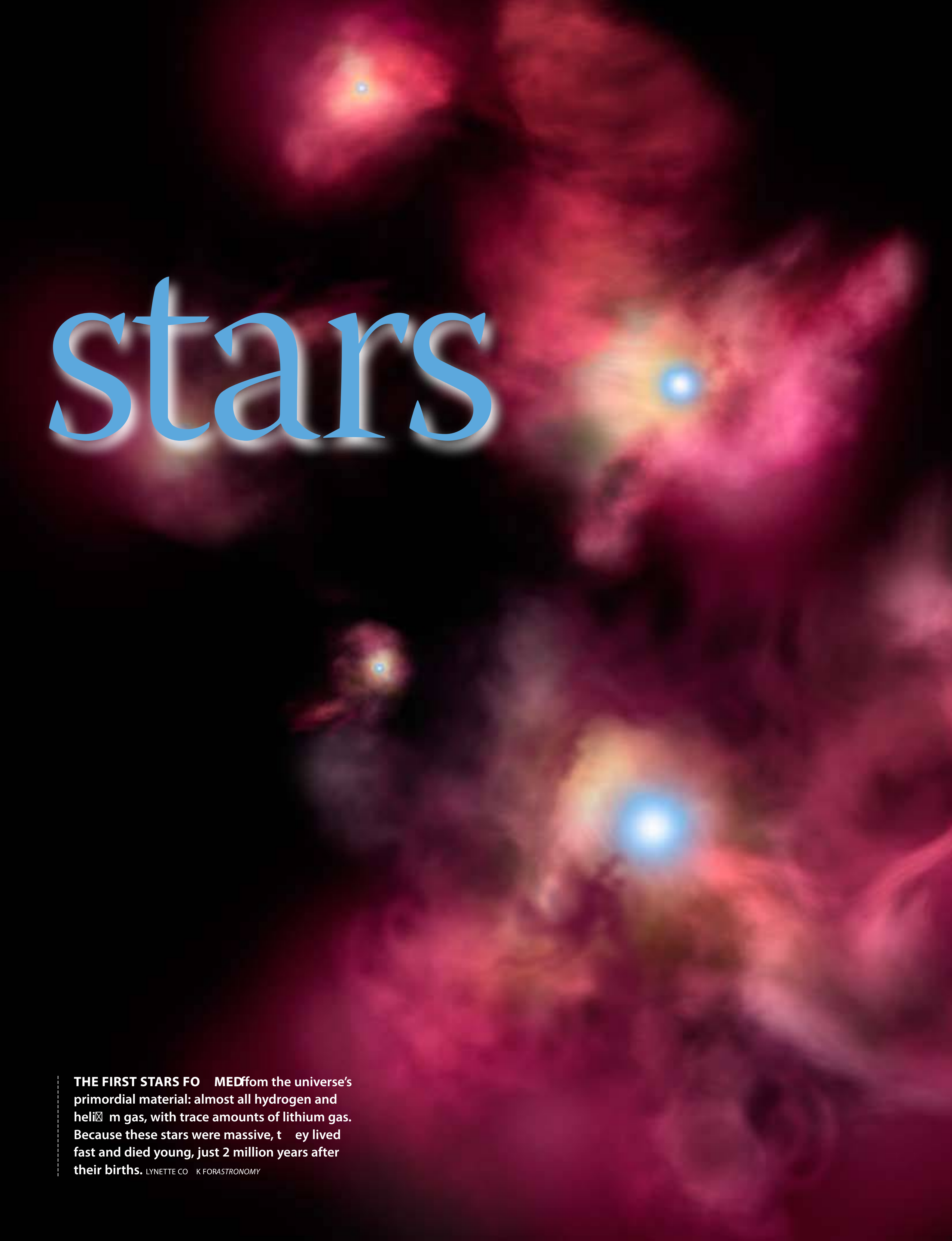
In the beginning, there were no atoms, only a dense, hot soup of electrons, protons, and other elementary particles moving around and scattering light at all wavelengths. As the infant universe expanded and cooled below a few thousand Kelvin, protons could hold on to electrons to make neutral atoms of hydrogen and helium for the first time. The cosmic microwave background, the relic glow of the hot, early universe, carries the imprint of cosmic structures at the time of this transition, 380,000 years after the Big Bang. That etching is remarkably smooth, with density variations at the level of only 1 part in 100,000.

Ray Jayawardhana, *a professor of astronomy and astrophysics at the University of Toronto, studies the formation of planets, brown dwarfs, and stars.*

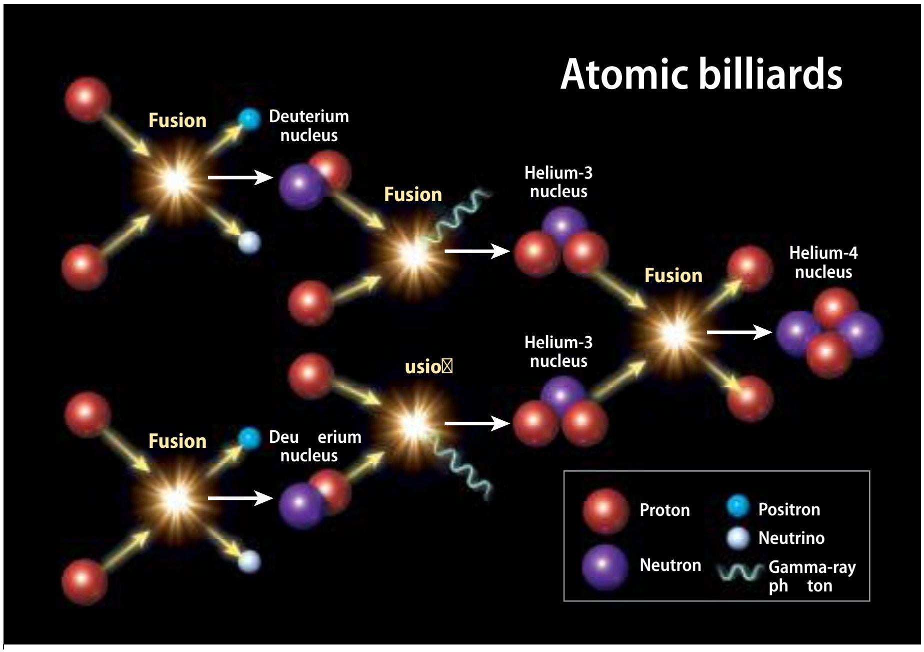
Cosmologists are now using sophisticated computer simulations and deep observations with giant telescopes to unravel the tale of how the first stars and galaxies grew out of those tiny ripples. It's a story shrouded in darkness, literally. Between the time neutral atoms formed and the moment the first stars lit up, the universe was in its so-called Dark Ages. Thus, there's little chance for us to see directly the buildup of the first objects. Instead, we have to rely on theory to guide us.

With sufficiently powerful telescopes, we can expect to see the effects of those first stars on their environment and their immediate descendants — and, in turn, test the theoretical

stars



THE FIRST STARS FORMED from the universe's primordial material: almost all hydrogen and helium gas, with trace amounts of lithium gas. Because these stars were massive, they lived fast and died young, just 2 million years after their births. LYNETTE COOK FOR *ASTRONOMY*



ASTRONOMY: ROEN KELLY

STARS SHINE as a result of energy released during nuclear reactions. The simplest reaction — nuclear fusion — combines, or fuses, hydrogen nuclei together to produce helium and neutrinos. As a result, energy is released. Extremely high temperatures are required to combine nuclei. The universe's primordial material was mostly hydrogen and helium nuclei. Once the gas collapsed enough because of gravity, they were both hot enough and close enough together to fuse. And then there was light: The first stars lit up.

predictions. We have observed some galaxies and quasars shining brightly a billion years after the Big Bang, so the first stars must have formed sometime earlier.

Making the first stars

It may seem futile to try to figure out the birth of the first stars in the distant, unobservable past when our understanding of present-day star formation is far from complete. But, in some ways, the recipe was simpler back then. We don't need to include the complicating influences of magnetic fields threading gas clouds or shocks from nearby supernovae in the prescription for the very first stars.

The only ingredients in the mix were hydrogen, helium, and traces of deuterium and lithium — plus "dark matter." Dark matter accounts for over 80 percent of matter in the universe, and its influence is felt primarily through gravity. And one doesn't need to worry about the cooling effects of heavier elements or dust produced by previous generations of stars.

In recent years, astronomers have set up elaborate computer codes to follow the formation of the first stars. Perhaps the most detailed simulations are those done by Tom Abel of Stanford University, Greg Bryan of Columbia University, and Michael Norman of the University of California, San Diego (see "The universe's first light" on page 46). Another group, including Volker Bromm of the University of Texas, Austin, and Yale University's Richard Larson and Paolo Coppi, has done simulations using a simpler set of assumptions. However, this team explored a wider range of possibilities.

All of these simulations show that the minuscule density fluctuations in the early universe — the lumps in the primordial soup — acted as seeds for growing gas clouds. These fluctuations became the nodes of a network of filaments along which more gas continued to flow in. These clouds contracted under their own gravity and heated up to over 1,000 kelvins.

A small number of hydrogen atoms paired up to become hydrogen molecules, which helped cool the gas by emitting infrared radiation. Once the temperatures in the densest regions dropped to a few hundred kelvins, the cloud clumps could contract further. The cooling was crucial: It allowed ordinary matter, which cooled by emitting radiation and therefore continued contracting, to separate from dark matter. The dark matter didn't cool and thus remained scattered throughout the cloud.

Some of the densest gas clumps collapsed until they lit up. Because cooling by small numbers of hydrogen molecules isn't very efficient, these star-forming clumps were much warmer than their counterparts today. (Dust grains and other molecules cool present-day clouds more efficiently.) The gas clumps also had to be more massive in order for gravity to overcome the outward pressure from the hotter gas. This means the first star-forming clumps were probably several hundred times more massive than the Sun.

Did all of that mass go into a single star? Even the most-detailed simulations do not show any tendency for these clumps to fragment as they contract. Thus, theorists think the first stars were rather massive and luminous: Estimates for the upper mass limit range from about 300 to 1,000 solar masses, and the luminosities could have been millions of times that of the Sun.

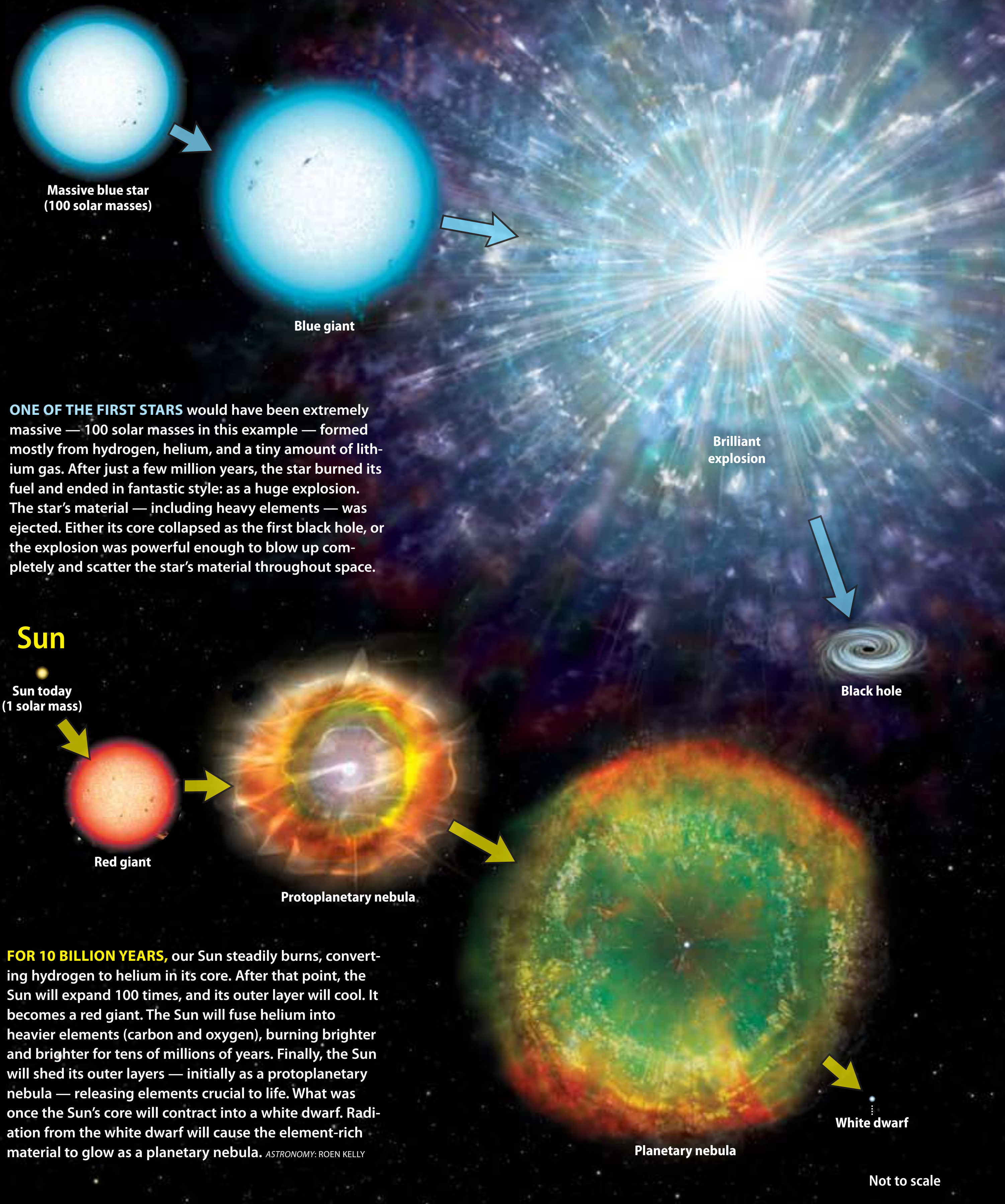
The cosmic dawn

The birth of these first-generation stars marked the cosmic dawn. These behemoths were also extremely hot, with surface temperatures approaching 20 times that of the Sun. They emitted primarily ultraviolet light. Their energetic radiation would have started to heat and ionize the neutral hydrogen atoms in their vicinity, carving out a hollow bubble of ionized gas around each one. As more and more stars formed over hundreds of millions of years, these bubbles would overlap, until nearly all the gas in the universe became ionized.

> The first stars' ejecta polluted surrounding gas with ingredients for dust, planets, and even life ...

Most of the first stars probably ended their brief, but brilliant, lives as exploding supernovae within a few million years. Theory predicts stars with masses between 140 and 260 times that of the Sun blow up completely, expelling the heavier elements they produce through nuclear fusion. The first stars' ejecta polluted surrounding gas with ingredients for dust, planets, and even life, and were eventually incorporated into future generations of stars.

The first stars and their descendants


First star
Massive blue star (100 solar masses)
Blue giant
Brilliant explosion
Black hole
Sun
Sun today (1 solar mass)
Red giant
Protoplanetary nebula
Planetary nebula
White dwarf
Not to scale

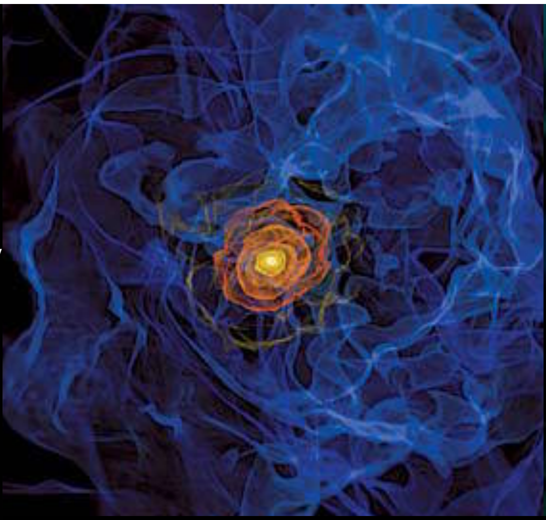
ONE OF THE FIRST STARS would have been extremely massive — 100 solar masses in this example — formed mostly from hydrogen, helium, and a tiny amount of lithium gas. After just a few million years, the star burned its fuel and ended in fantastic style: as a huge explosion. The star's material — including heavy elements — was ejected. Either its core collapsed as the first black hole, or the explosion was powerful enough to blow up completely and scatter the star's material throughout space.

FOR 10 BILLION YEARS, our Sun steadily burns, converting hydrogen to helium in its core. After that point, the Sun will expand 100 times, and its outer layer will cool. It becomes a red giant. The Sun will fuse helium into heavier elements (carbon and oxygen), burning brighter and brighter for tens of millions of years. Finally, the Sun will shed its outer layers — initially as a protoplanetary nebula — releasing elements crucial to life. What was once the Sun's core will contract into a white dwarf. Radiation from the white dwarf will cause the element-rich material to glow as a planetary nebula. *ASTRONOMY:* ROEN KELLY

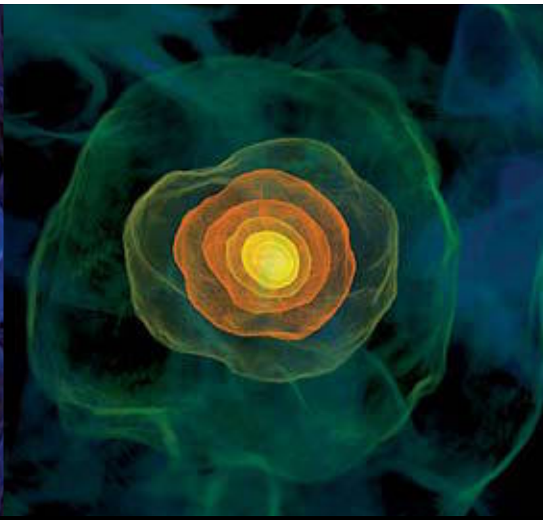
The universe's first light

THE FIRST STAR to form was massive — between 30 and 300 solar masses — and sat inside the first forming protogalaxy, as shown by Tom Abel, Greg Bryan, and Michael Norman in their computer simulations. Hydrogen and helium gas — the universe's primordial material — contracted to form the earliest generation of stars. These huge stars burned bright, lived fast, and died young — after just a 2-million-year life cycle.

VISUALIZATION: RALF KÄHLER AND TOM ABEL
SIMULATION: TOM ABEL, GREG BRYAN, MICHAEL NORMAN



At 65 light-years (20 parsecs) across, this shows cold gas in the center of one of the first protogalaxies.



Follow the contours to zoom inside clumps of different gas densities. One star will form in the center, where the density is highest.

Both above and below this mass range, dying massive stars are expected to collapse into black holes without ejecting much of their mass. They didn't enrich their progeny by much. But their remnant black holes have lit up as "mini-quasars" as they accreted surrounding material, providing additional sources of light and ionizing radiation that brought the Dark Ages to an end.

Some of the stellar corpses may have merged with one another to build up the cores that seeded protogalaxies. This could explain why supermassive black holes appear to lurk in the centers of quasars and many galaxies. Thus, the demise of the first stars was perhaps even more important than their birth to all that came afterwards.

There is little chance of catching the first stars in their spectacular death throes even with today's largest telescopes. But some of them may have given rise to gamma-ray bursts, which are much more luminous than supernovae, at the edge of the observable universe. Detecting such a distant gamma-ray burst is our best hope for probing the end of the Dark Ages directly.

From an ancient era

In the meantime, other ways to investigate those early days exist: by looking for the effects of those first stars on their surroundings. In 2001, a group of astronomers led by Robert Becker of the University of California, Davis, detected possible signs of the final stages of cosmic reionization.

In the spectrum of one of the most distant quasars known, dating to about 900 million years after the Big Bang (at a redshift of 6.4), they found a telltale signature of neutral gas: Essentially all of the quasar's ultraviolet light had been absorbed by hydrogen atoms in the line of sight.

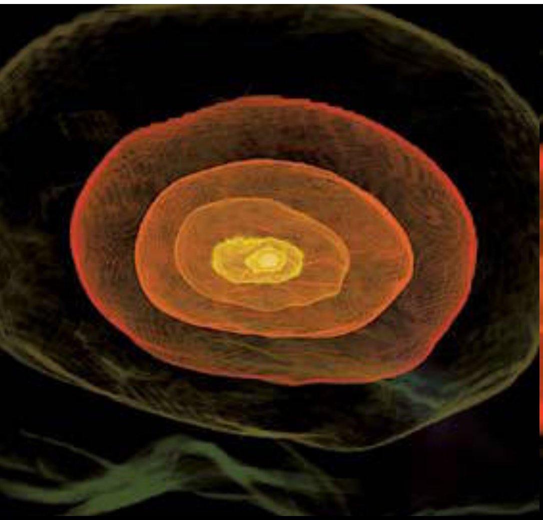
Slightly less distant quasars do not show such complete absorption. These findings suggest the last patches of neutral hydrogen gas were ionized around that time.

There has been a new twist. Preliminary measurements of the degree of polarization in the cosmic background by NASA's Wilkinson Microwave Anisotropy Probe (WMAP) satellite indicate the universe was reionized much earlier — sometime between 200 and 500 million years after the Big Bang (at a redshift of 10–20), rather than at 900 million years, as implied by the quasar observations. These findings may show the two ends of the reionization period: one the beginning, and one the end.

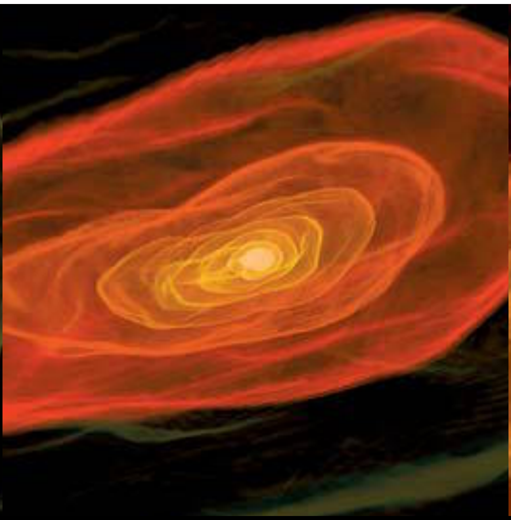
The apparent discrepancy between the WMAP and quasar results remains "a genuine big puzzle, and no one knows the physical mechanism that can explain such an extended reionization history," says Zoltan Haiman of Columbia University. The answer may come from the European Space Agency's Planck satellite, to be launched in 2007, which will make more reliable measurements of polarization in the cosmic microwave background.

Finding different methods

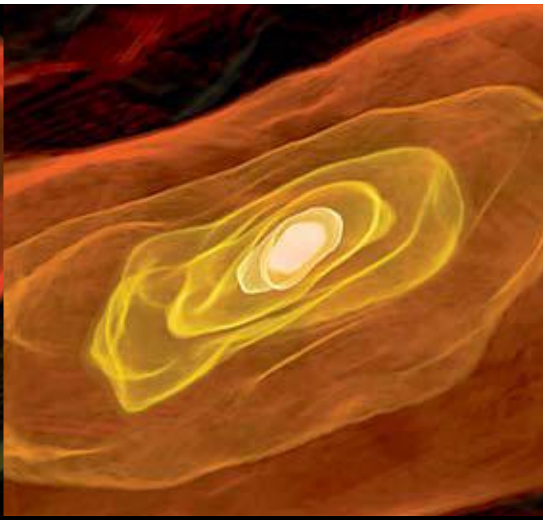
Astronomers would like to find other, perhaps even more distant, quasars and galaxies that could contain the second generation



The gas density rises rapidly as the primordial gas radiates and collapses faster and faster.



At the center of the protogalaxy, where the gas density is greatest, material continues to collapse into a star.



The white-hot first staX — roughly 10 times ⌧ ur solar system's width — burns uickly because of its ⌧ assive size.

of stars. Simulations predict these protogalaxies would b small and relatively faint.

Several ur⌧ ys haZe been⌧ undertaken recently, using the Japanese-built Subaru Telescope in Hawaii and the European Southern Observatory's Very Large Telescope in Chi _, to look ⌧ or s⌧ ch o⌧ jeT s network of radio dishes now being built in northeln Chile⌧ — the Ataca a Large Mi limeter Array — will search for distant star-forming galaxies at millimeter wavelengths.

The observers have come up empty so far. Unless they get lucky, success may have to await the launch of the James Webb Space Telescope, the planned successor to Hubble, or the constru⌧ tio⌧ of ⌧ 20- o 30-meter optical telescope on the ground.

Directly detecting neutral hydrogen is another way to probe the reionization era. Hyd⌧ ogen atoms emit⌧ photo_s at a cha- a teristic wavelength of 21 centimeters, in the radio. This radiation from the early universe would be redshifted to longer wavelengths — a few meters — by the time it reaches us.

Several new radio observatories are planned for the near future to look fbr hydrogen's signature. The Low-Frequency Ar ay (L[FAR), wit 15,000 ⌧ ntennae spread over 100 kilometers, is under construction in the Netherlands, and its prototype is taking data. Ue-Li Pen of the Canadian Institute for Theoretical Astrophysics and his colla⌧ or⌧ tors in the United States a⌧ d Chin wa⌧ t to be⌧ +n seirahing sooner and at low costb They are "planting" thousands of commercially available TV nte⌧ nae o a remote plateau in China and expect to do the first searches for hydrogen emission within the next year.

In our own neighborhood

Other astronomers are searching for clues closer to home⌧ b e⌧ the f⌧ rst s[ars lived fast And died yo0ng, low-mass stars that formed soon after their deaths may still lurk in the Mi ky Way's halo. Element abundances in the atmospheres of these old and iron-poor second-generation stars could tell u how their massive progenitors lived and died.

Thus, the demise of the first tars was perhaps⌧ even more important than their birth ...

Within the past few years, astronomers have identified two such "hyper-met l-poor" (HMP) stars. HE 0107–5240 and HE 1327–2326 contain $^{1}/_{200,000}$ and $^{1}/_{300,000}$ of the Sun's iro/ abundance, respectively. However, these iron-deficient stars are enhanced in other (lighter) elements, such as c rbon.

This was a surprise: Previous theoretical ca culations suggested much iron, but only small amounts of carbon, would be ejected during the deat throes of he first stars and incorporated into the next generation. Timothy Beers of Michigan State Univers⌧ ty describes HMP stars as "scribes" of the early universe. "Their atmospheres retain th2 memory o⌧ the composition of the gas' from which they formed," he explains.

To account for the unexpected abundance pattern seen in these two stars, their progenitors must have included stars with asses as low as 25 times that of the Sun, according to a new theoretical model by Nobuyuki Iwamoto and his colleagues in Japan. To test this emerging scenario, astronomers are now looking for other examples of ancient, iron-poor stars. It isn't easy to find t⌧ em because they are dim+and usually live in he outskirts of the galaxy.

The Sloan Digital Sky Survey's recent extension includes a search called the Sloan Extension for Galactic Understanding and Evolution (SEGUE). This study will collect spectra of 250,000 stars in the Milky Way over the next 3 years, and it may reveal other candid tes for⌧ HMP s⌧ ars that coul⌧ give us valuable clues to what came befo e.

Clearly, we haven't unraveled the full story of the cosmic dawn yet. Some missing chapters may be deciphered in the spectra of old stars in the Milky Way's halo. Other parts would be revealed in snapshots from billions of l-ght-ye⌧ rs away. And plot twists could emerge as astronomers put the pieces together over the next decade. A

ONLINE EXTRA To see more computer simulations of the first stars, check out www.astronomy.com/toc

{ ASTRONOMICAL HISTORY }

The man who DOUBLED the sky

In 1833, John Herschel's family name took him to South Africa to map the southern sky, and his determination made him a legend. /// BY ROBERT ZIMMERMAN

NATIONAL MUSEUM OF PHOTOGRAPHY, FILM & TELEVISION

John Herschel was already an accomplished astronomer when he arrived in South Africa to map the southern skies in 1834. He had completed a detailed, 8-year sweep of the Northern Hemisphere by 1833, and resolved shortly thereafter to complete "a survey of the whole surface of the heavens."

Herschel took his telescope equipment some 6,000 miles from his home in England to Cape Town, South Africa. From March 1834 to January 1838, he spent every clear night at his telescopes. He swept the entire southern sky, cataloging everything he saw.

The night of December 19, 1837, put an exclamation point on one of the most ambitious astronomical projects ever undertaken by one person. Herschel was surprised to see something that had not been there before. "[The star] had come on suddenly," he wrote in a letter to Thomas Maclear, the astronomer at the Royal Observatory at Cape Town.

At first Herschel thought the new star might be a supernova similar to those recorded in 1572 and 1604. After careful measurement, he realized the unexpected spark was the star Eta (η) Carinae, shining 3 times brighter than he had ever seen it.

He stared at this puzzling object into the wee hours of the morning. John was able to document Eta Car's 1837 outburst, a

BY THE END OF HIS LIFE, John Herschel, photographed here by renowned photographer Julia Margaret Cameron, had not only doubled the known sky, but also dabbled in photography, chemistry, and law.

specific stage in its lifecycle. Today, astronomers use both Herschel's observations and modern data to learn more about the late stages in this massive star's evolution.

The scope of Herschel's achievement is astounding. He cataloged more than 1,200 new nebulae and star clusters, made detailed observations of Halley's Comet (in 1835), and he studied both Saturn and Uranus. His detailed survey of the star distribution across the entire sky made it possible for astronomers finally to determine that the Milky Way is a gigantic disk of stars, within which the Sun resides.

All told, he must have viewed more than 40 million stars during the 12 years he cataloged the entire heavens.

The family business

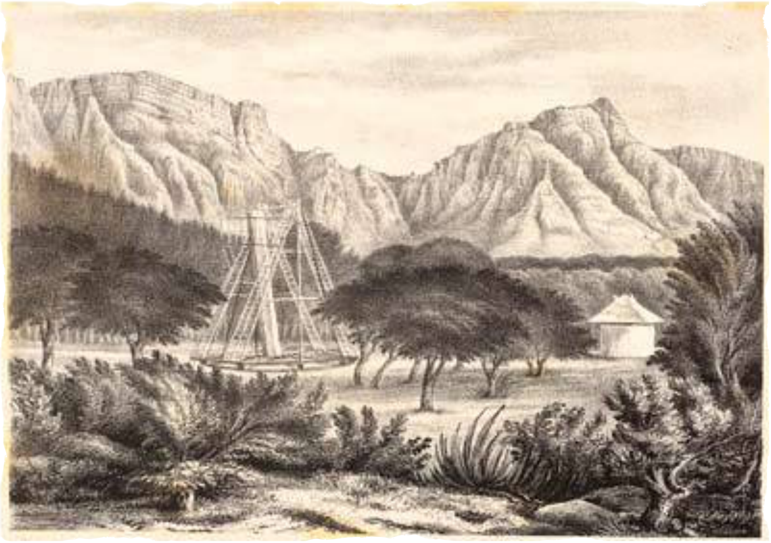
For someone who might dream of becoming a famous astronomer, John Herschel could not have been born into a more fortunate circumstance.

His father, William Herschel (1738–1822), is one of history's most renowned astronomers. William was trained as a musician and composer, but later switched to astronomy, becoming passionate about exploring the heavens. When he discovered most available telescopes were too small and poorly made for the precise observations he wished to do, he began making his own, and reinvented the art of telescope-making. His telescopes had 6 times the resolution of any scientific telescope, and 6,000 times the resolution of the best ordinary telescopes.

William then reinvented the very nature of astronomical research. In the 1700s, astronomers focused mostly on astrometry — trying to pinpoint the locations of stars and planets. William Herschel instead turned his eye to the deep sky, doing careful and thorough sky surveys, accurately cataloging everything he saw there. Thus, he wasn't surprised when he discovered Uranus. "In the regular manner I examined every star in the heavens. ... It was that night its turn to be discovered."

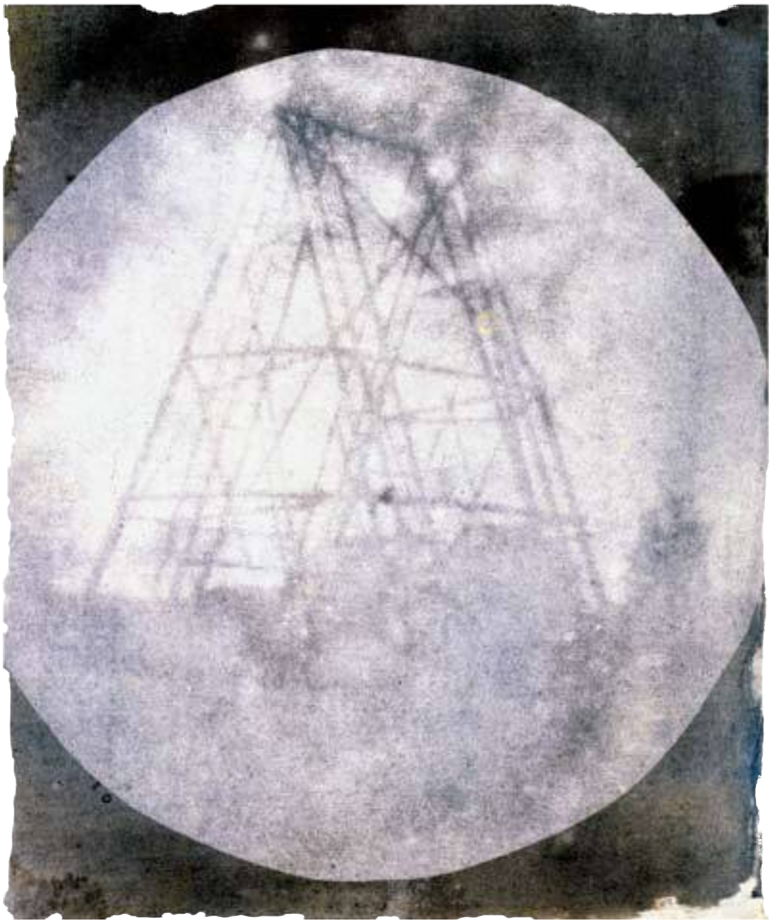
The discovery of Uranus made him famous and wealthy. King George III

Robert Zimmerman *hopes his last article for* Astronomy, *"The Looming Death of Hubble" (November 2004), has helped save the telescope.*



G. H. FORD AFTER J. W. HERSCHEL, *RESULTS OF ...* FROM MICHAEL E. BAKICH COLLECTION

HERSCHEL'S 20-FOOT TELESCOPE at his private observatory at Feldhausen had an 18.5-inch primary mirror. This lithograph, after Herschel's drawing, is the opening image of Herschel's *Results of Astronomical Observations made during the years 1834-38 at the Cape of Good Hope*.



SCIENCE MUSEUM, LONDON

Herschel took one of the earliest glass-plate photographs September 9, 1839. He imaged his father's 40-foot telescope in Slough, England.

/// EARLY TABLOID

THE GREAT MOON HOAX

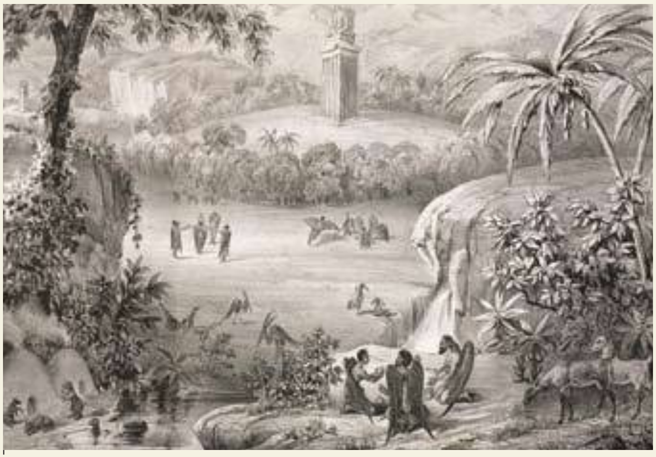
The original *New York Sun* newspaper ran a story from August 25–31, 1835, about John Herschel's discoveries at the Cape. According to the *Sun*, Herschel published new findings in the *Edinburgh Journal of Science*. (The journal had ceased publication years prior to the hoax. Not many people knew this, and they believed the *Sun*'s information.)

Supposedly, Herschel had invented a telescope with a magnification power of more than 6,000x that could resolve features 18 inches in diameter on the Moon's surface.

The *Sun* claimed he'd observed a variety of surface features: rolling fields of flowers, huge quartz formations in a rainbow of colors, and forests of trees. The lunar creatures were even more amazing: lunar bison, unicorns, huge birds, bipedal beavers, and winged humanoids — which the *Sun* said were called *Vespertilio-homo*, or man-bats.

Herschel had no idea this story was published until weeks later, and competing newspapers couldn't argue the truth of the story because there was no way to reach Herschel quickly.

The "Great Moon Hoax" made the *New York Sun* the best-selling newspaper for years. The *Sun* later admitted the story was false — Richard Adams Locke, a reporter with the *Sun*, wrote it — but no one was angry, not even Herschel. Everyone found it amusing. — *Liz Kruesi*



SCIENCE MUSEUM, LONDON

MAN-BATS, **lush vegetation, and bipedal beavers were just a few of the odd things Herschel supposedly saw, as reported in the "Great Moon Hoax" of 1835. This is a print made by the Thierry brothers in 1838, after the hoax was exposed.**

appointed William the Royal Astronomer. He socialized with the famous and powerful, becoming close friends with all of the well-known astronomers of his day.

When John was born in 1792, his father could offer him the best education, a wealthy inheritance, and the personal guidance to make him the greatest astronomer who had ever lived.

John, however, was not sure he wanted to spend his life staring at the stars. At St. John's College, Cambridge, his talent seemed to favor mathematics. Not only did he receive top honors repeatedly; he, along with Charles Babbage and George Peacock, helped revolutionize British mathematics by forcing the abandonment of Newton's notation system in favor of Europe's more efficient mathematical symbols.

When he finished his studies at Cambridge in 1813, he made the surprising decision to enter law. He enrolled at Lincoln's Inn, and, for the next few years, made a halfhearted attempt to become a lawyer.

John's first loves were chemistry and optics, and, while at Lincoln's Inn, he continued his experiments. He even applied for the chair of chemistry at Cambridge but was turned down.

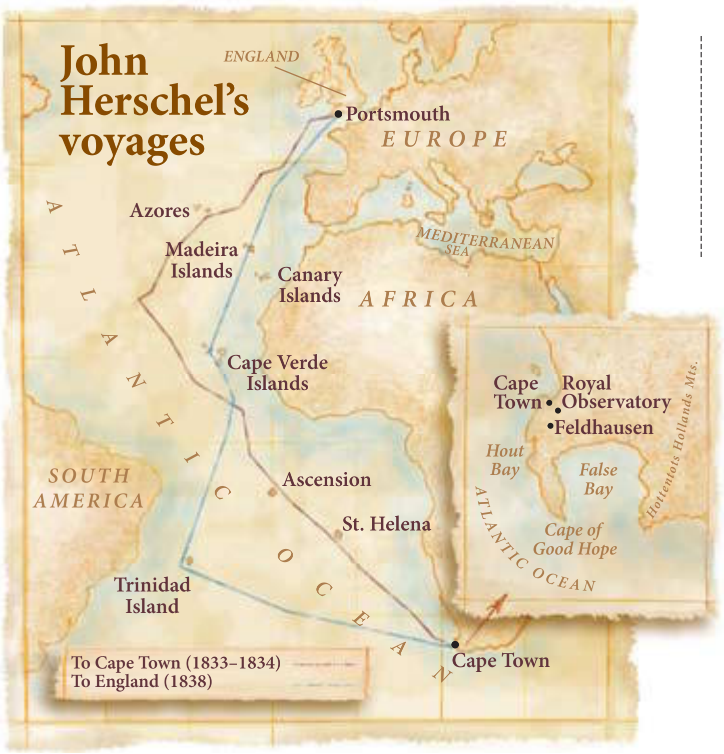
In 1816, with his legal career fizzling, and an academic career in chemistry blocked, John joined his father at the telescope, helping him finish his last sweeps of the Northern Hemisphere.

More important, John accepted his father's tutelage at making telescopes. In the next few years, John learned all Pi li could teach him, unquestionably becoming the world's best telescope-maker.

Yet, astronomy remained a chore, not a love. Even though he tackled the work with diligence and skill, completing his own catalog of the northern sky, John was not always happy at his work. At one point, in 1830, he described his frustration to his wife, threatening "to break the telescopes and melt the mirrors."

To go or not to go

What made his astronomy accomplishments even more remarkable was the difficulty entailed in making southern sky observations. In the 300 years since Ferdinand Magellan had first seen the galactic clouds



ASTRONOMY: JAY SMITH

HERSCHEL and his entourage spent months at sea traveling from England to South Africa in 1833–1834, and back to England in 1838.

that are named for him, only a handful of professional astronomers had traveled below the equator. Furthermore, in the 1830s, Cape Town was little more than a small colonial town, accessible only by a long sea voyage.

In the late 1600s, Edmond Halley had spent 2 years on the island of St. Helena in the southern Atlantic. From 1751 to 1753, Abbé Nicolas Louis de Lacaille had gone to South Africa and mapped about 10,000 stars while also roughing out a southern constellation map. Then, from 1823 to 1827, James Dunlop went to Paramatta in Australia to catalog stars and nebulae.

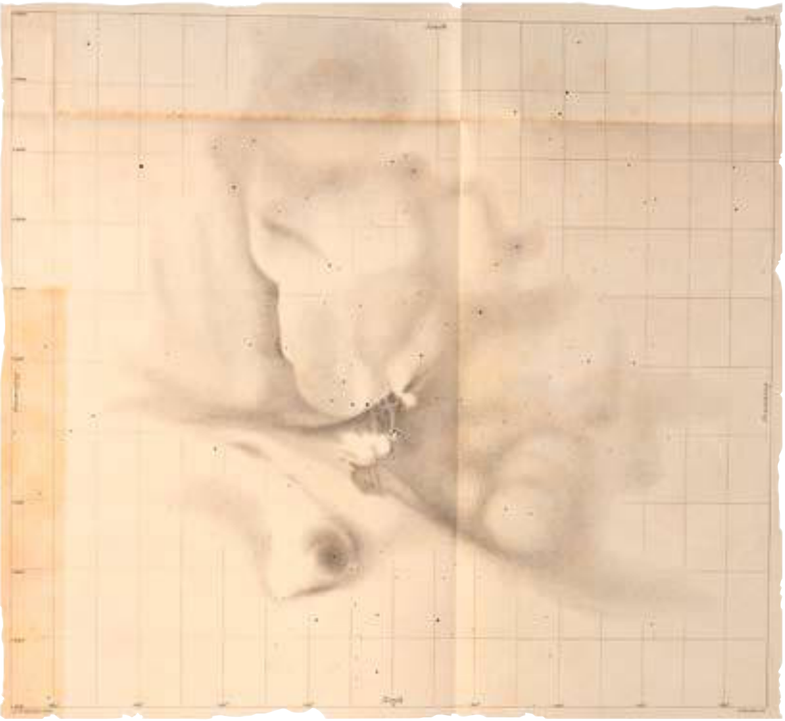
However, these efforts were spotty and crippled by inadequate or imprecise equipment. For example, John Herschel could not confirm more than a third of the nebulae Dunlop listed; the locations given for the other two-thirds were wrong.

By the 1820s, the astronomical community began to address the lack of southern sky observations. In 1820, England established an observatory in Cape Town, South Africa, with Fearon Fallows as the first Royal Astronomer there in 1826. That same year, the Berlin Royal Academy began hinting of its own project to map the southern sky. By 1830, England's Royal Society had formed a committee to discuss the subject.

Clearly, if the Herschel family was going to be the first to map the southern sky, John would have to act soon. John had the same skills as his father, and since John had already mapped the northern sky, if he took his telescopes with him, he could do the southern sky using the same instruments as he used previously. From a scientific point of view, such an opportunity was priceless.

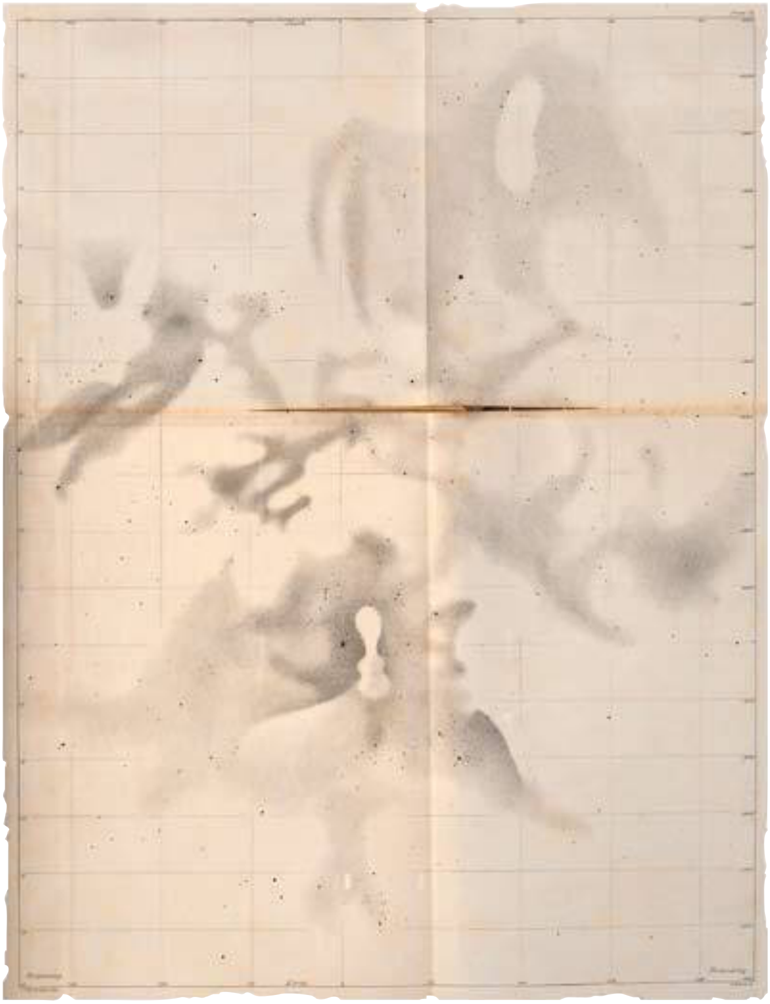
So, in 1830, Herschel researched what a journey to the Southern Hemisphere would entail. Finding a place to work was difficult because only a few remote colonial settlements existed. Herschel considered Australia, but he eventually decided on Cape Town. It had been under British rule since 1814, and British trading ships made regular stops there on their way to and from China and the East Indies. More importantly, the Royal Observatory was there, implying a level of familiar civilization.

Establishing his own observatory half a world away would not be easy. Herschel planned on bringing two telescopes with him. The larger telescope, a handbuilt 20-foot reflector that used an 18.5-inch mirror, would be used for the full survey, while a more maneuverable 7-foot equatorially-



J. W. HERSCHEL, *RESULTS OF ASTRONOMICAL* ... FROM MICHAEL E. BAKICH COLLECTION

THE GREAT NEBULA IN ORION shows an incredible amount of detail in this pencil-on-card drawing by Herschel.



J. W. HERSCHEL, *RESULTS OF ASTRONOMICAL* ... FROM MICHAEL E. BAKICH COLLECTION

also known as the Carina Nebula, surrounds the star Eta (η) Carinae, which brightened dramatically in late 1837.

/// FAST FACTS

BIOGRAPHY

- **Name:** John Frederick William Herschel
- **Date of birth:** March 7, 1792
- **Place of birth:** Slough, England
- **Date of death:** May 11, 1871
- One of the founders of the Royal Astronomical Society, and its first president
- Knighted in 1831
- Coined the terms *positive* and *negative*
- Created one of the first glass-plate photographs
- His catalog includes 68,948 stars, 1,708 nebulae and star clusters, and 2,102 double stars
- He cataloged 1,269 nebulae and star clusters for the first time
- Awarded the Copley Medal, the Royal Society's highest honor, in 1847
- Buried at Westminster Abbey, London, close to Isaac Newton

YERKES OBSERVATORY PHOTOGRAPHIC SERVICES

JOHN HERSCHEL was not, as many might imagine, an elderly man when he made his discoveries at the Cape of Good Hope; he was in his mid-forties.

mounted reflector would measure double stars' orbital motion precisely.

To use the larger scope, Herschel had to disassemble, pack, and reassemble the 20-foot-high scaffolding and rope winch that held it in place. Furthermore, the 7-footer required the construction of a protective housing with a revolving roof, much of which Herschel designed and built himself.

Because precise glass mirrors were not available, he used polished metal mirrors that tarnished easily. He brought three interchangeable mirrors for the 20-footer, as well as the equipment to repolish them regularly.

Herschel hired his chief assistant and mechanic, John Stone, who had helped him during his survey of the northern skies.

He also could not leave for several years without bringing his wife Margaret and their three children (aged 3 years, 2 years, and 10 months). He even brought his personal butler, John Rance, a governess for the children, and an entire household of goods.

He booked four cabins on the *Mountstuart Elphinstone*, packed, and sailed from Portsmouth, England November 13, 1833.

At the Cape

Two months later, the entourage arrived at Cape Town. Herschel wasted no time setting up. He found a piece of property dubbed Feldhausen (which means "the grove" in Dutch), located on the outskirts of Cape Town. By February 22, 1834, he had the 20-footer assembled and was able to take his first look at the sky.

ONLINE EXTRA Read excerpts from Herschel's Cape journal at www.astronomy.com/toc

"I feel so enervated," he wrote, "that I have scarce heart enough to crawl backwards and forwards [home] — and only can be said to exist after sunset." By early March, he did his first sweeps of the sky using his father's technique: pointing the telescope due south to the meridian, then tilting it to a specific right ascension, and letting Earth's rotation sweep it through a 3° swathe. During the next 4 years, he did just under 400 sweeps, methodically working his way around the southern sky. When the sky was clear and the Moon was dim or new, he was up all night, carefully cataloging every object that came into his field of view.

The work was not always pleasant. The awkwardness of bending over the telescope caused his right ankle to swell up. The area was infested with fleas and poisonous snakes, and the family had to fight several nearby forest fires to prevent their home from burning. During the 4-year stay in Cape Town, the nanny died, and Herschel's wife gave birth to three more children.

Nonetheless, Herschel considered his years at the Cape "the sunny spot in my whole life where my imagination will always love to bask. It is a dream — and too sweet a dream not to be dashed by with the dread of waking."

His southern sky survey discovered more than 1,200 new nebulae and star clusters, including the Ring Nebula (M57) in the constellation Lyra. In addition, he studied the star density across the entire sky, counting almost 70,000 stars in 2,299 fields, and proving the stellar population density increases dramatically closer to the plane of the Milky Way.

Herschel found few stars toward the Milky Way's poles, noting, for example, how "access to the [Small Magellanic Cloud] on all sides is through a desert." In these empty regions, he found a surplus of nebulae and clusters, including a remarkable concentration of nebulae around Virgo, now known as the Virgo supercluster of galaxies.

This contrast of star counts proved our solar system is part of what Herschel called "a vast stratum, or considerably flattened and unsymmetrical congeries of stars."

In his inventory of double stars, he carefully measured their relative positions. In one double system, Gamma (γ) Virginis, he saw one star slowly creep behind the other in its 171-year orbit. By mapping the star's orbit, he confirmed Newton's theory of gravitation applied throughout the universe.

In the age before photography, he documented the Keyhole's shape and topography.

He observed the second predicted return of Halley's Comet in 1835, noting how the distorted shape and sudden growth of the comet's coma and tail could result only from a force originating in the Sun's direction.

Herschel studied the Sun as it approached solar maximum and underwent one of its more active sunspot cycles — he observed some of the largest spots ever seen. "The black center of the spot of May 25 [1837] would have allowed the earth to drop through it."

Herschel didn't simply catalog what he saw in the sky. Noting the imprecise methods used to determine stellar magnitude, he built what he called an astrometer, the first instrument to measure a star's apparent magnitude precisely.

Nor did he limit himself to astronomy. He made careful observations of the geology and flora around him, drawing more than 200 previously unknown plants. The trilobite fossils he found and shipped to England became a species named after him.

And he observed the first known outburst of Eta Car, believed by many scientists to be one of the best candidates to go supernova in the relatively near future. His observations provide today's astronomers with a detailed view of one stage in this strange star's evolution. During the next 30 years, Eta Car faded from 1st to 7th magnitude, while parts of the larger Eta Car nebula around the Keyhole nebula faded, and its namesake no longer stands out so distinctly.

In the age before photography, he documented the Keyhole's shape and topography by drawing a careful map and marking the positions of more than 1,200 stars to lock down the nebula's appearance.

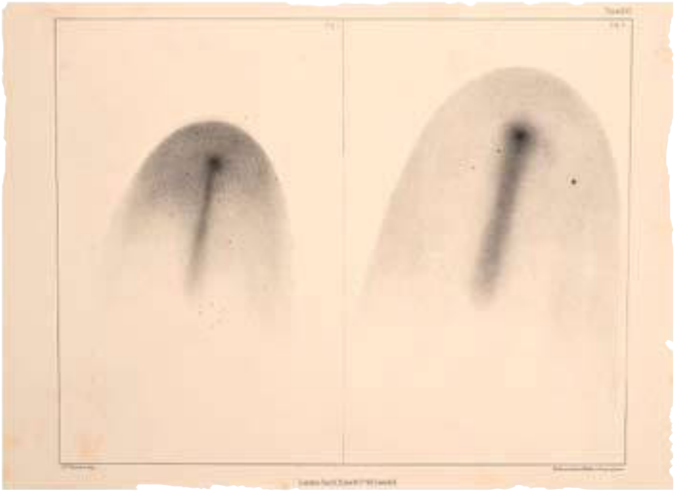
The fruits of labor

After his return to England in the spring of 1838, Herschel essentially gave up research astronomy. The 20-footer was abandoned — its mirror tarnished in the cellar of his country house. He spent 10 years writing up his results, then dabbled in chemical and photographic experiments before becoming England's Master of the Mint.

Although travel to the Southern Hemisphere had been possible for centuries, few astronomers had made the voyage before Herschel. He saw the need, and grabbed it.

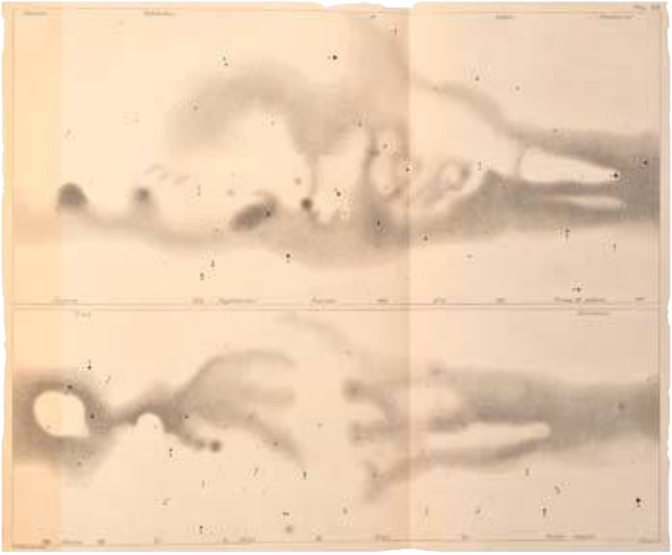
Herschel had a choice. He could have abandoned astronomy and studied chemistry and photography, both of which interested him more. Instead, he put his interests aside to become the first person to observe the southern sky closely. Had he not made this choice, astronomy's advance would have been delayed, and we would know much less about Eta Car's 1837 outburst.

Astronomy needed someone with persistence and determination, and that was John Herschel. ▪



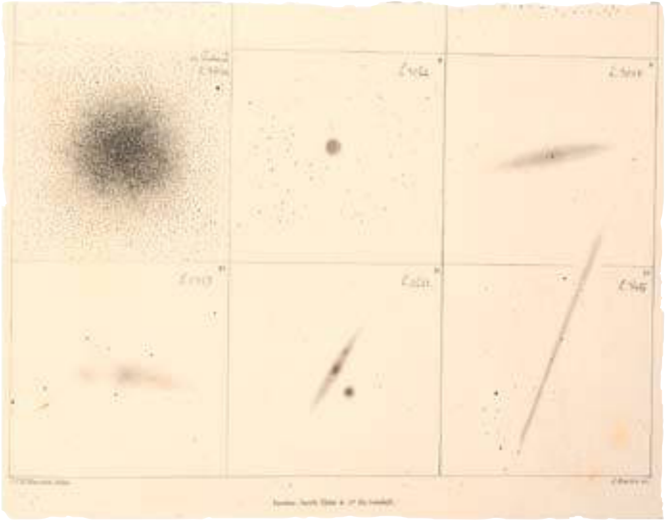
J. W. HERSCHEL, *RESULTS OF ASTRONOMICAL* … FROM MICHAEL E. BAKICH COLLECTION

WHEN HALLEY'S COMET made an appearance in 1835, Herschel took advantage of the event and made these detailed sketches of the comet's coma and tail.



J. W. HERSCHEL, *RESULTS OF ASTRONOMICAL* … FROM MICHAEL E. BAKICH COLLECTION

THE HIGH CONCENTRATION OF STARS in the Milky Way's plane makes the central area look like a cloud of stars, as shown in Herschel's sketch.



J. W. HERSCHEL, *RESULTS OF ASTRONOMICAL* … FROM MICHAEL E. BAKICH COLLECTION

HERSCHEL CATALOGED more than 1,700 nebulae and star clusters and sketched a variety of them.

{ PLANETARY SCIENCE }

Odd couples

From near Earth to beyond Pluto, binary asteroids are everywhere. **Dan Durda** explains why.

If two's company and three's a crowd, then the field of minor-planet-satellite studies just got pleasantly crowded.

In August 2005, Franck Marchis at the University of California, Berkeley, and his colleagues announced the discovery of a second small moon orbiting the main-belt asteroid 87 Sylvia. Remus, the new moonlet's name, joins its larger brother Romulus (discovered in 2001) in what is becoming a veritable zoo of minor-planet satellites.

This collection of orbiting companions is adding whole new dimensions to our understanding of the origin and evolution of the solar system's smallest citizens. And this new knowledge could play a key role in protecting Earth from a future asteroid impact.

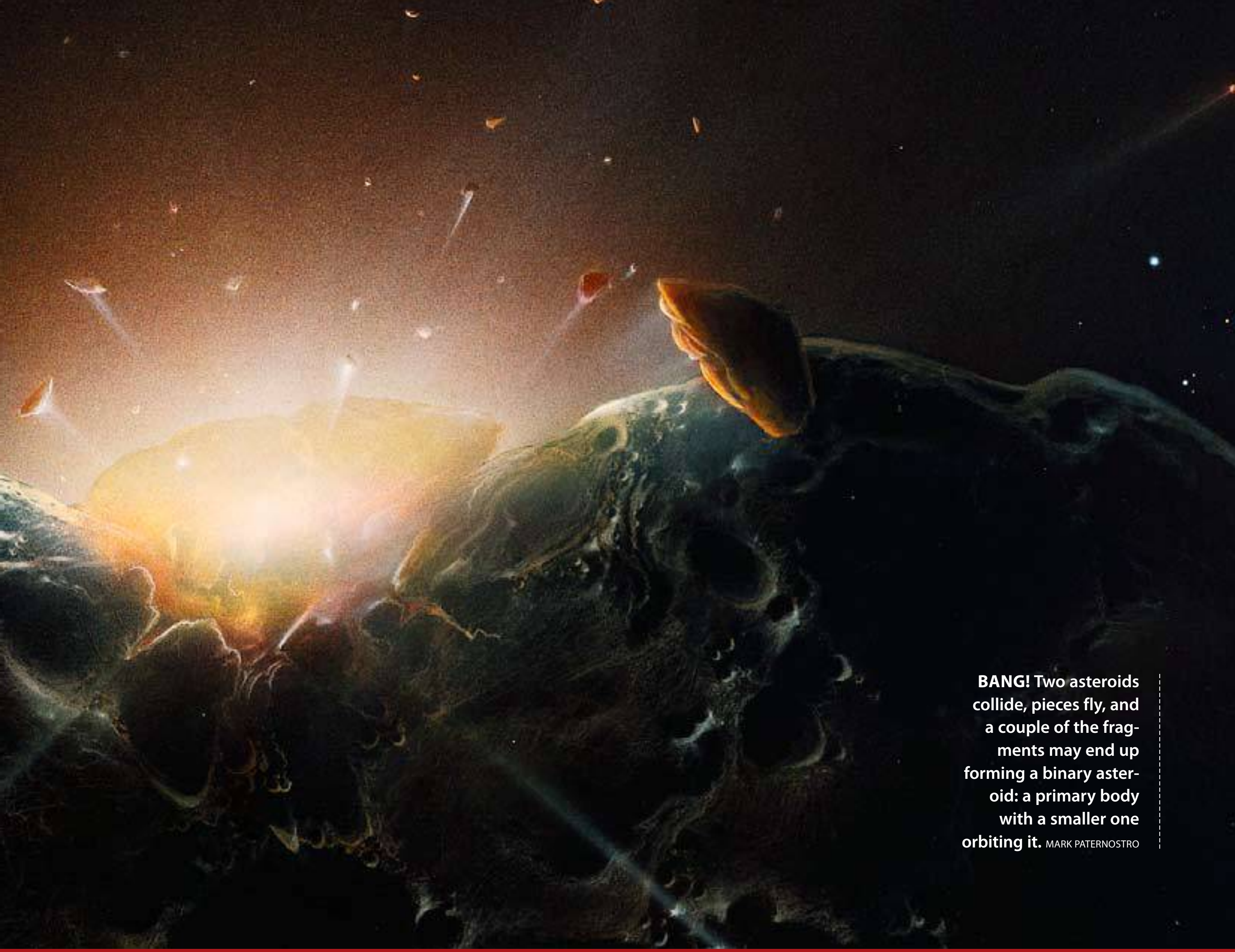
But long before today's asteroid surveys began turning up minor-planet moons, planetary astronomers had wondered if asteroid satellites were even possible. Could a small body with almost no gravity of its own hold on to a yet-smaller object, amid gravitational perturbations and jarring catastrophic impacts? No one really knew.

Dan Durda *is a planetary scientist at the Southwest Research Institute in Boulder, Colorado. In his spare time, he also paints astronomical subjects.*

Hunting for moons

English astronomer William Herschel conducted the first — though unsuccessful — search for an asteroid satellite in 1802, shortly after the discovery of the first asteroid, 1 Ceres. In 1901, French astronomer Charles André thought he detected a satellite orbiting the near-Earth asteroid 433 Eros, because a plot of its changing brightness resembled that of a binary star whose two components periodically eclipse each other. The idea was sound, but André was mistaken — a century later, detailed images from the NEAR-Shoemaker spacecraft, which orbited and finally landed on that asteroid, showed that Eros is moonless. André had been misled by Eros' elongated shape.

By the late 1970s, some astronomers thought they had detected moons orbiting some minor planets. Asteroids passing in front of (occulting) stars showed secondary blinkouts, although so far none of the candidates has been confirmed by subsequent observations.



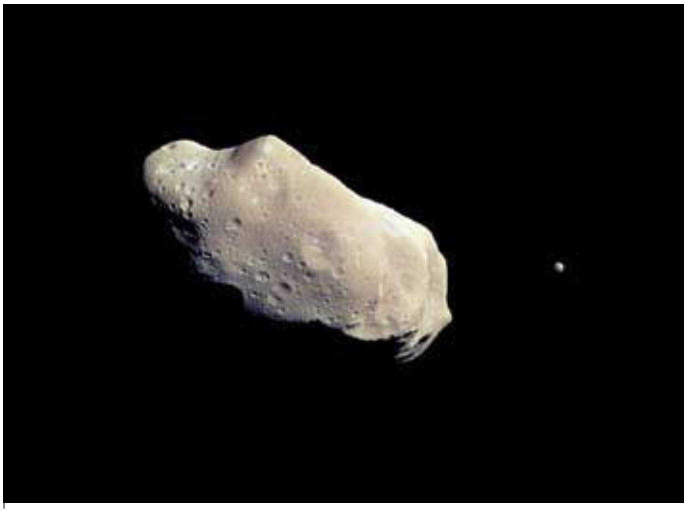
BANG! Two asteroids collide, pieces fly, and a couple of the fragments may end up forming a binary asteroid: a primary body with a smaller one orbiting it. MARK PATERNOSTRO

Even searches with speckle interferometry, a precursor to today's high-resolution adaptive optics, turned up no solid leads. As the 1990s began, some asteroid scientists were writing the epitaph of minor-planet satellites.

Astonishment at Ida

That all changed August 29, 1993. The Galileo spacecraft, bound for Jupiter, flew past the main-belt asteroid 243 Ida. Because Galileo transmitted data at a much slower rate than originally planned, the operations team came up with a bandwidth-saving technique. Rather than sending back bit after bit of blank space from the mosaic of images gathered during the Ida flyby, the team played back two or three lines out of every 20 to 40. These "jailbar" images let scientists preview where the useful data would be, and the technique successfully located the high-resolution images of Ida taken near closest approach.

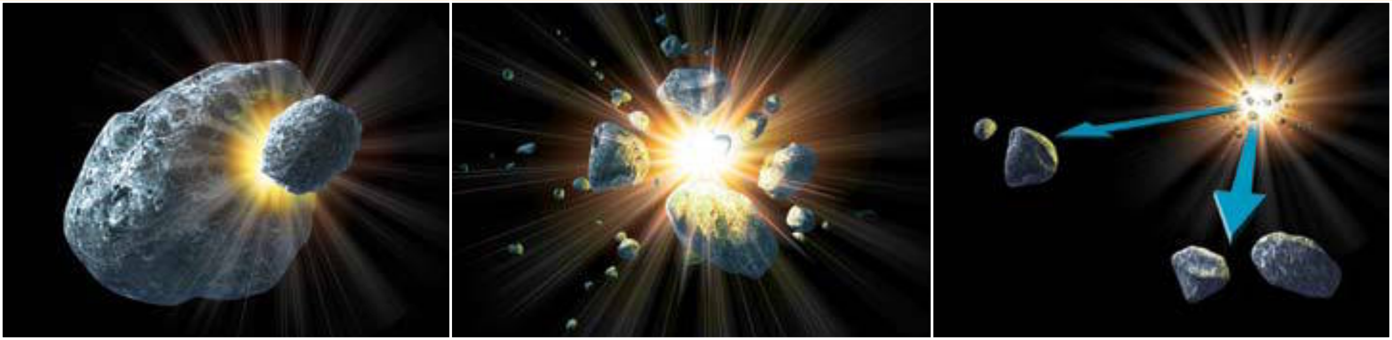
On February 17, 1994, after a 5-month hiatus in playback, the imaging team was scheduled to receive a jailbar image taken about 10 minutes before Galileo's closest approach to Ida. Ann Harch,



NASA/JPL

LONG SUSPECTED, binary asteroids became reality in August 1993, when the Galileo spacecraft flew past Manhattan-size Ida — and spotted its tiny moon, Dactyl.

MAKING A DOUBLE ASTEROID



COLLISIONS are a way of life for all asteroids. High-speed computers let planetary scientists model what happens when two such bodies collide.

THE SMASH makes pieces of all sizes and may even destroy the original colliders. The fragments fly off in every direction at a variety of speeds.

IF FRAGMENTS leave the scene with nearly the same speed and direction, their mutual gravity may form a double asteroid or an asteroid with a small moon.

ASTRONOMY: ROEN KELLY, AFTER DAN DURDA

an operations engineer for the imaging team, was instrumental in planning the encounter sequence.

"When the data hit the ground," she recalls, "I got a call from Lisa Wainio at the image-processing facility at JPL [Jet Propulsion Laboratory]. She implied cryptically there was something very odd about the image. But we were not prepared for what we found in that image. Straddling a single jailbar line were 15 brightly lit pixels stranded in the darkness off the bright limb of Ida. My first words were something like 'What is *that?!*'"

"That" turned out to be Dactyl — a 0.93-mile-diameter (1.5 kilometers) satellite of Ida, and the first unmistakable discovery of a minor planet's moon.

Asteroids *do* have satellites!

More than a curiosity

Finding Dactyl was a triumph for planetary science, however accidental its discovery may have been. For scientists, studying the physical properties of asteroid satellites, and understanding the mechanisms that make these little moons, opens a valuable window into the solar system's evolution.

Once you've discovered a satellite orbiting an object, Kepler's third law of planetary motion lets you determine the combined mass of the pair. If the satellite is much smaller than the body it orbits, then most of the mass lies in the primary object. If the size of the primary asteroid is known (or the size-ratio of both objects is known), you can then reliably estimate the asteroid's density.

Density is fundamentally important. It gives planetary scientists crucial clues to the composition and internal structure of objects. Is the asteroid a solid, monolithic mountain of rock — or is it a porous pile of bashed-to-bits rubble? A satellite's presence around a particular asteroid may often be the only clue to gain these insights.

Likewise, the sizes and orbital properties of individual satellites, as well as systematic similarities and differences among binaries, can give us important clues to how these pairs formed.

Since the discovery of Ida's moon, Dactyl, new ground-based searches have turned up additional satellite systems, demonstrating the Ida-Dactyl pair is no fluke. Nearly six dozen satellite systems have now been discovered. They inhabit every population of small bodies that astronomers know of: main-belt asteroids, near-Earth asteroids, and Kuiper Belt objects (KBOs) in the frozen realm beyond Neptune's orbit. The discoveries suggest that minor-planet satellites are not unusual. Instead, they appear to be consequences of common, ongoing processes.

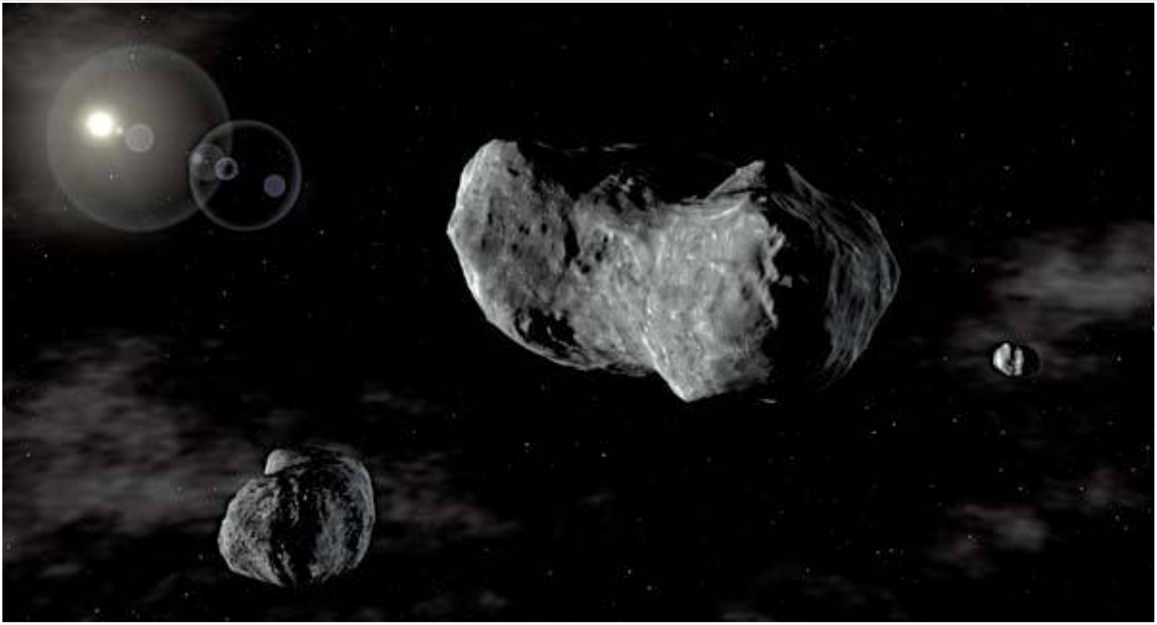
Widening the census

The first Earth-based discovery of an asteroid satellite came in 1998, when Bill Merline of the Southwest Research Institute and his colleagues found a moon orbiting the main-belt asteroid 45 Eugenia. Merline's group was using the relatively new technique of adaptive optics at the Canada-France-Hawaii Telescope to survey hundreds of main-belt asteroids for possible satellites. By reducing the blurring effects of Earth's atmosphere, adaptive optics allows large ground-based telescopes to compete with the sharp-eyed resolution of space-based telescopes.

Since the discovery of Eugenia's moon, named Petit-Prince, Merline's group and others have found more than two dozen satellites orbiting asteroids in the main belt between Mars and Jupiter, and in the Jupiter Trojan asteroid population. (A Trojan asteroid circles the Sun in the same orbit as a major planet but about 60° ahead of or behind the planet. Trojans accompany Jupiter and Neptune, and probably Saturn and Uranus, too.)

These binary systems range in configuration from large, 120-mile-diameter (200 km) primaries with small, 6-mile (10 km) moons orbiting hundreds of miles away, to true double asteroids with nearly equal-size components.

Asteroid-and-satellite systems are found among all types of asteroids, from the rocky S-types to the primitive C-types to the metallic M-types. (Most of the observed binaries in the main belt



ESO ARTWORK

THE FIRST KNOWN TRIPLE ASTEROID is Sylvia, with a distant moon named Romulus (discovered in 2001) and a smaller one, Remus, orbiting closer. Remus was discovered in 2004 and announced in 2005.

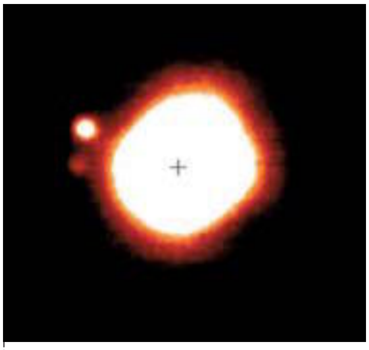
and Trojan region are primitive types, however.) So far, it appears that a few percent of all main-belt asteroids have moons orbiting them — although that fraction undoubtedly will rise as observing techniques improve and allow for the discovery of more small, close-in moons like Remus orbiting Sylvia.

One mechanism for all?

Because collisions are the dominant geologic process affecting main-belt asteroids today, scientists conclude most of the satellites are byproducts of catastrophic impacts with other asteroids. When a parent asteroid completely breaks up, it might eject some debris fragments on nearly identical trajectories. Mutual gravity could then capture two pieces to form an orbiting pair. In other cases, ejecta from large cratering events may end up orbiting an asteroid and accreting into a small satellite.

My own research team, which includes Bill Bottke, Brian Enke, and Bill Merline at the Southwest Research Institute; Erik Asphaug of the University of California, Santa Cruz; and Derek Richardson and Zoe Leinhardt of the University of Maryland has been simulating collisions between asteroids to study satellite formation.

We model collisions between asteroids using a computer code that calculates the pressures, temperatures, and fragmentation that occur during impacts. When the simulations are complete — after crater formation and ejecta flows are established, and when no further fragmentation or damage will occur — we use the fragments' positions and velocities as the starting conditions for so-called N-body simulations. These calculate the gravitational interactions among hundreds of thousands of fragments and follow their evolving trajectories to look for the formation of satellite systems.



UC BERKELEY, F. MARCHIS

TWO MOONS peek out beside the overexposed image of Sylvia. Potato-shaped Sylvia has a length of 236 miles (380 km), Romulus is 11 miles (18 km) across, and Remus is 4 miles (7 km) across.

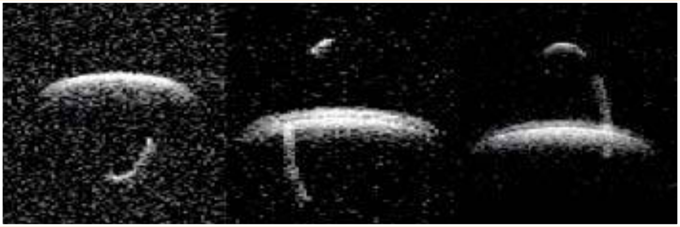
Using these numerical simulations, we have produced satellite systems wholly consistent with those observed in the main asteroid belt. There is, thus, a beautiful synergy between the observed properties of actual binaries and simulation results of their formation. This allows us to use these satellite systems as natural laboratories to better understand the collision history and evolution of the asteroid belt.

Minor moons everywhere

Among near-Earth asteroids (NEAs), planetary scientists have found several satellites by radar observations and through unexpected eclipses in light-curves. In 1995, Petr Pravec of the Ondrejov Astronomy Institute in the Czech Republic concluded the complex light-curve of 1994 AW$_1$ could best be explained by occultations and eclipses occurring in a binary system. He found the same for a second NEA, 1991 VH. The first confirmed NEA binary, 2000 DP$_{107}$, was discovered by radar in September 2000 at the Goldstone radar facility in California's Mojave Desert. Shortly thereafter, scientists used the Arecibo radio observatory in Puerto Rico to determine the system's orbital parameters, mass, and density.

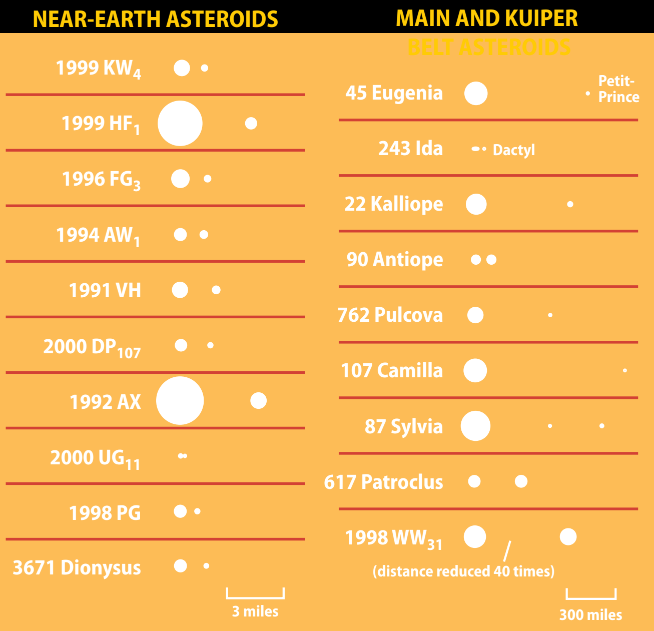
Since that confirmation, observations at Goldstone and Arecibo have revealed increasingly spectacular radar images of several other binary NEAs. Radar observations often provide crucial details on the components' sizes and shapes and on the system's orbital parameters.

NEAs collide with themselves and with main-belt asteroids, so they may generate moons through the same impact processes that make satellites in the main belt. But there's a process at work on NEAs that their main-belt cousins never see.



RADAR PAINTS a striking picture of the binary asteroid 1999 KW$_4$ in three frames taken over several hours with NASA's Goldstone radar. The primary body, 0.8 mile (1.2 km) wide, appears large because of its fast rotation, and gaps in the satellite's trail come from gaps in data collection.

NASA/JPL, S. OSTRO



RELATIVE SIZES AND SPACING vary among the asteroid populations, with near-Earth binaries typically much closer to each other than their cousins in the outer solar system.

ASTRONOMY: ROEN KELLY, AFTER W. R. JOHNSTON

Tidal forces can spin up or completely disrupt some NEAs that pass too close to the terrestrial planets. (A decade ago, this process broke up Comet Shoemaker-Levy 9 when it passed close to Jupiter.) In 1998, scientists Derek Richardson (now at the University of Maryland), NASA's Stan Love, and Bill Bottke showed some fragments produced by close passes can become orbiting satellites or binary pairs when they reaccumulate by gravity. In fact, the observed frequency of satellites in the near-Earth asteroid population (about 15 percent) nicely explains the statistics of double impact craters on Earth, like the Ries and Steinheim craters in Germany, and the Clearwater East and West craters in Canada.

The effects of tidal disruption also hint at these asteroids' internal structures. To be torn asunder by relatively weak tidal stresses during a swing past a planet like Earth means they can't be solid, monolithic mountains of rock. Instead, they have to be loosely cohesive — essentially rubble piles.

In the cold and dark

Beyond the orbit of Neptune, even the solar system's deep freeze — the Kuiper Belt — contains binaries. The first Kuiper Belt object was discovered in 1992. Scientists have since identified more than 900 additional worlds there (out of a population estimated to be some 100,000 objects larger than 60 miles [100 km] in diameter).

Since Christian Veillet discovered the first KBO satellite in December 2000, another 12 binary systems have been observed by direct imaging using both ground-based instruments and the Hubble Space Telescope. This brings the total number of KBO satellites to 14 out of some 900 known primaries, including the Pluto-Charon system. (Pluto, while formally considered a planet, is physically more like the Kuiper Belt objects.)

The KBO binaries discovered so far have components with comparable sizes and wide orbital separations ranging from about 60 to 1,000 times the primary asteroid's radius. Pluto and Charon are an exception because Charon orbits Pluto only 16 Pluto radii away.

The large, widely separated binary pairs observed in the Kuiper Belt appear to require a different formation mechanism from those in the main asteroid belt or the NEA population. In the primordial days of the outer solar system, scientists think, the Kuiper Belt contained more objects in less-varied orbits than today. In those conditions, temporary binaries may have formed when large objects approached near enough to each other that their mutual gravitational attraction was stronger than the disruptive tidal force of the distant Sun.

Peter Goldreich at Caltech and his colleagues propose that these transient pairs became stabilized through numerous encounters from smaller passing objects or by the gravitational interaction of a nearby third large body. Alternatively, Yoko Funato at Tokyo University and colleagues propose that some large KBOs may already have had satellites made through the same collisional mechanisms that act today in the main asteroid belt. If so, the gravitational do-si-do between large objects could evict small moons in favor of the larger passersby.

The bigger picture

As we scan the solar system, looking to inventory its contents, we are driven by a mix of motives. Naturally, we wish to learn as much as we can about the worlds around us and what they can tell us of our planet's origin.

But there's more than intellectual curiosity at work here. Earth has been struck by asteroids (and comets) many times in the past, and we have no wish to be counted as cosmic casualties. The discovery of binary asteroids opens the way to understanding the physical makeup of these objects. And this, in turn, can help humanity contemplate possible future impacts and the deflection techniques we might use to prevent them. ◼

ONLINE EXTRA Read how Ann Harch and her colleagues on the Galileo imaging team discovered Ida's moon, Dactyl, at www.astronomy.com/toc

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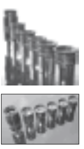

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BY MARTIN RATCLIFFE AND ALISTER LING

DECEMBER 05

You don't need a telescope to enjoy the Geminid meteor shower or the bright planets and twinkling winter stars on display this month.

Planets on parade

It's easy to appreciate the night sky's beauty without fancy equipment. Just step outside for 5 minutes and look around. About 45 minutes after sunset this month, brilliant Venus rides above the deepening orange twilight in the southwest. Meanwhile, the twinkling white star Fomalhaut breaks the quiet of the southern horizon, and the ruddy luster of Mars commands your gaze to the east.

Pop outside again around 9 P.M. local time to see Mars standing high in the south and winter's sparkling stars dominating the east.

Winter boasts more bright stars than any other season. Look to the east and you'll find reddish Betelgeuse and blue-white Rigel ruling Orion the Hunter. Gleaming Sirius and yellowish Procyon lie below Orion, while ruddy Aldebaran and golden Capella stand above.

The bright "star" low in the east won't be twinkling, however, a telltale sign it's really a planet. The pale, yellowish hue identifies it as Saturn. With binoculars, you can find the asteroid Vesta crawling through the star fields of Gemini.

As darkness starts to fall, focus on Venus. This cloud-covered world hits greatest brilliancy December 9, when it gleams at magnitude –4.6. Through a telescope, its beautiful crescent shape will delight all viewers. Venus is now approaching Earth rapidly, and as it does so, its telescopic appearance undergoes great change. Venus' disk swells more than 50 percent during December, while its phase thins from one-third lit to less than 10-percent illumination. At midmonth, Venus appears 3 times bigger than Mars.

ALAN DYER

ORION RISES over Mt. Rundle in the Canadian Rockies. The Hunter's return to the evening sky announces winter's arrival.

After you zero in on Venus, take a look at Mars. Although now past its peak, Mars appears bigger and brighter in early December than it will at any time in the next 10 years. Through a telescope, the fourth planet is a study in fleeting detail and low-contrast surface markings that reward patient observers. Avoid looking over rooftops, where escaping heat will blur the image. Persistence and practice are the keys to observing the Red Planet.

The crown jewel of the night sky is the ringed wonder, Saturn. Wait until late evening — once it has climbed above the worst of the low-level turbulence in Earth's atmosphere — to observe it. The planet's rings have closed quite a bit since spring. They'll appear edge-on in less than 4 years.

The Moon, new on December 1, makes a dramatic return to the evening sky when it pairs up with Venus on the 4th. Your eyes alone will give a great view, but use binoculars to best see earthshine, the ashen glow on the Moon's dark side caused by sunlight reflecting off Earth. Each day thereafter, earthshine gets harder to see as more of the Moon's visible hemisphere receives direct sunlight.

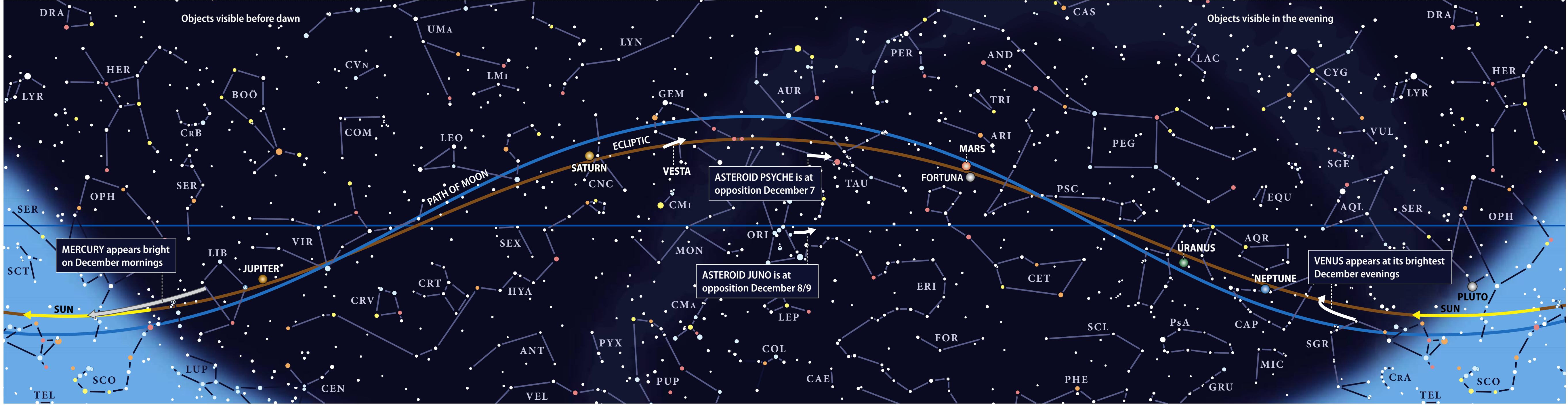
On December 11, the waxing Moon slices past Mars. If you have a digital camera, try your hand at a series of exposures to show the Moon's motion relative to Mars. The Moon moves the distance of its own diameter every hour.

The growing Moon plays havoc with this year's Geminid meteor shower. The annual shower peaks Tuesday night, December 13/14, just 1 day before Full Moon. Still, Geminid meteors are the year's brightest, so you should see up to 10 per hour if you view from a city backyard. You'll get better results (and have more fun) if you observe with friends away from the city.

Early risers can catch innermost Mercury as it puts on its best show of 2005. Look southeast around 6 A.M. local time, to the lower left of brilliant Jupiter. In the first few days of December, you'll need binoculars to spot the peach-colored dot. By the second week, it will be an obvious starlike point flickering through Earth's turbulent lower atmosphere.

Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.


Objects visible before dawn
Objects visible in the evening
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UMA
CVN
LMI
LYN
HER
LYR
BOÖ
CRB
COM
LEO
GEM
AUR
PER
CAS
AND
TRI
ARI
LAC
CYG
VUL
SGE
PEG
PSC
EQU
AQL
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OPH
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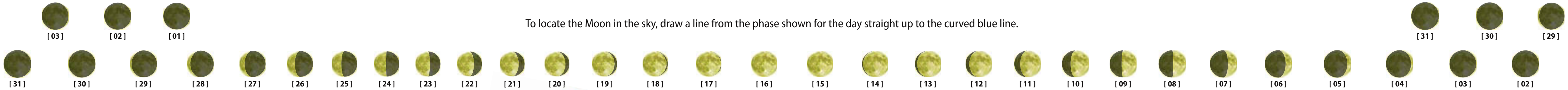
PATH OF MOON
SATURN
VESTA
MARS
FORTUNA
URANUS
NEPTUNE
PLUTO
JUPITER
SUN
ASTEROID PSYCHE is at opposition December 7
ASTEROID JUNO is at opposition December 8/9
MERCURY appears bright on December mornings
VENUS appears at its brightest December evenings

ALL ILLUSTRATIONS BY ASTRONOMY: ROEN KELLY

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.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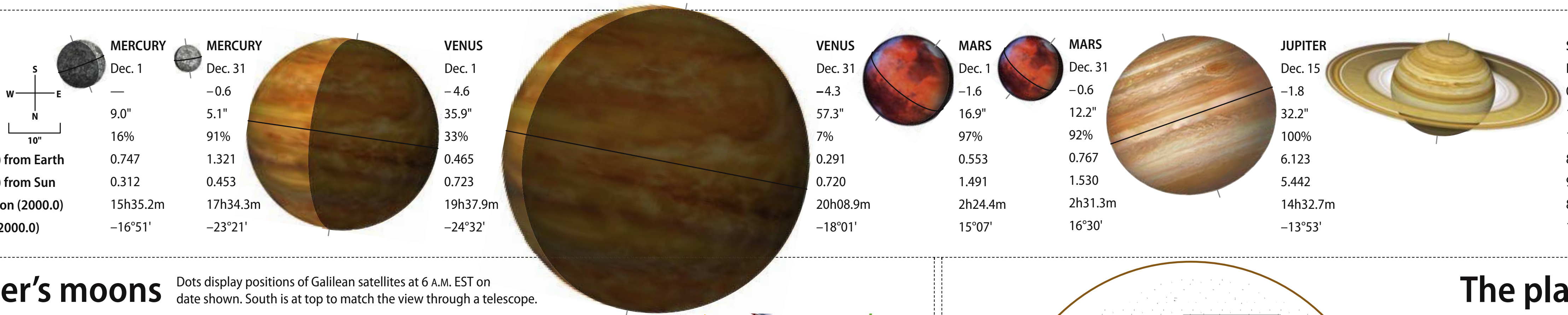
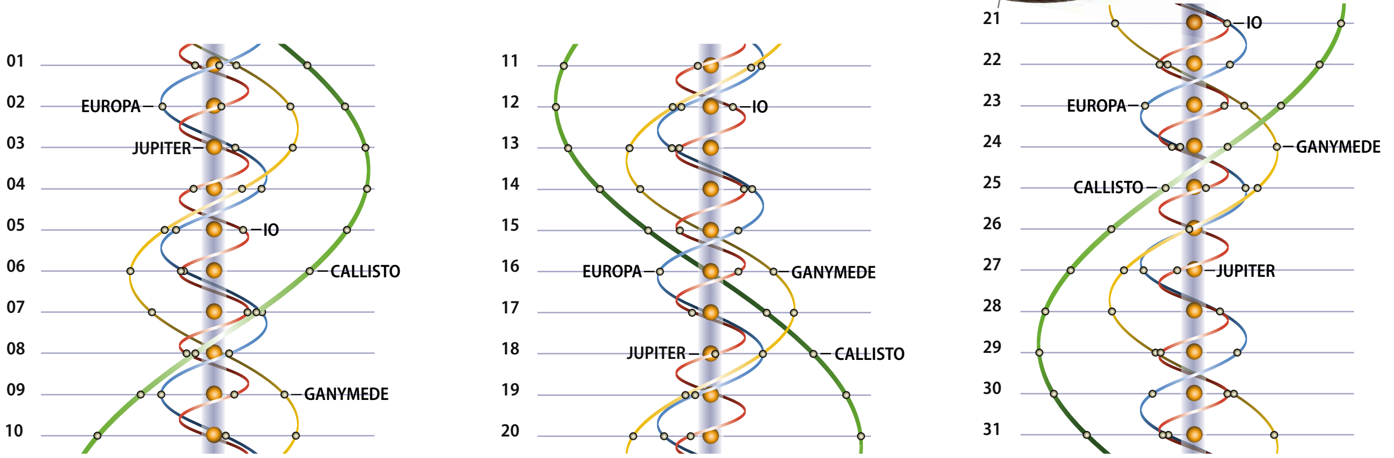


PLANETS	MERCURY	MERCURY	VENUS	VENUS	MARS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	Dec. 1	Dec. 31	Dec. 1	Dec. 31	Dec. 1	Dec. 31	Dec. 15	Dec. 15	Dec. 15	Dec. 15	Dec. 15
Magnitude	—	–0.6	–4.6	–4.3	–1.6	–0.6	–1.8	0.1	5.9	8.0	14.0
Angular size	9.0"	5.1"	35.9"	57.3"	16.9"	12.2"	32.2"	19.8"	3.5"	2.2"	0.1"
Illumination	16%	91%	33%	7%	97%	92%	100%	100%	100%	100%	100%
Distance (AU) from Earth	0.747	1.321	0.465	0.291	0.553	0.767	6.123	8.413	20.322	30.649	32.021
Distance (AU) from Sun	0.312	0.453	0.723	0.720	1.491	1.530	5.442	9.104	20.074	30.058	31.045
Right ascension (2000.0)	15h35.2m	17h34.3m	19h37.9m	20h08.9m	2h24.4m	2h31.3m	14h32.7m	8h53.5m	22h36.5m	21h11.6m	17h36.0m
Declination (2000.0)	–16°51'	–23°21'	–24°32'	–18°01'	15°07'	16°30'	–13°53'	18°06'	–9°36'	–16°22'	–15°50'

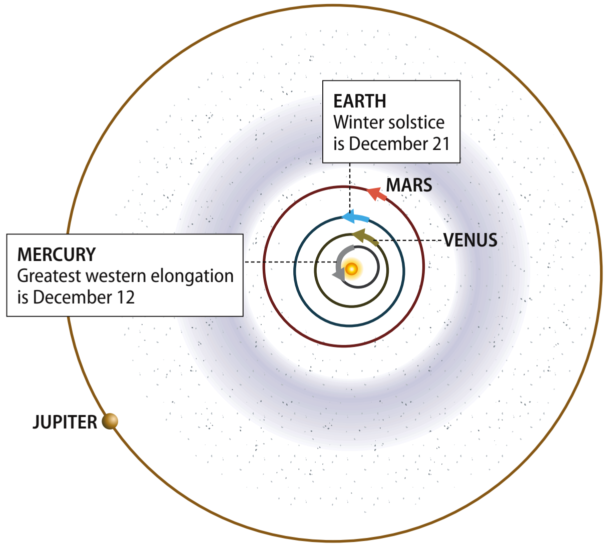
Jupiter's moons

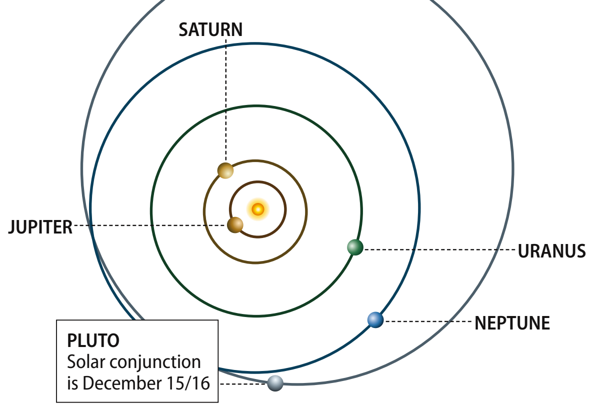
Dots display positions of Galilean satellites at 6 A.M. EST on date shown. South is at top to match the view through a telescope.



The planets in their orbits

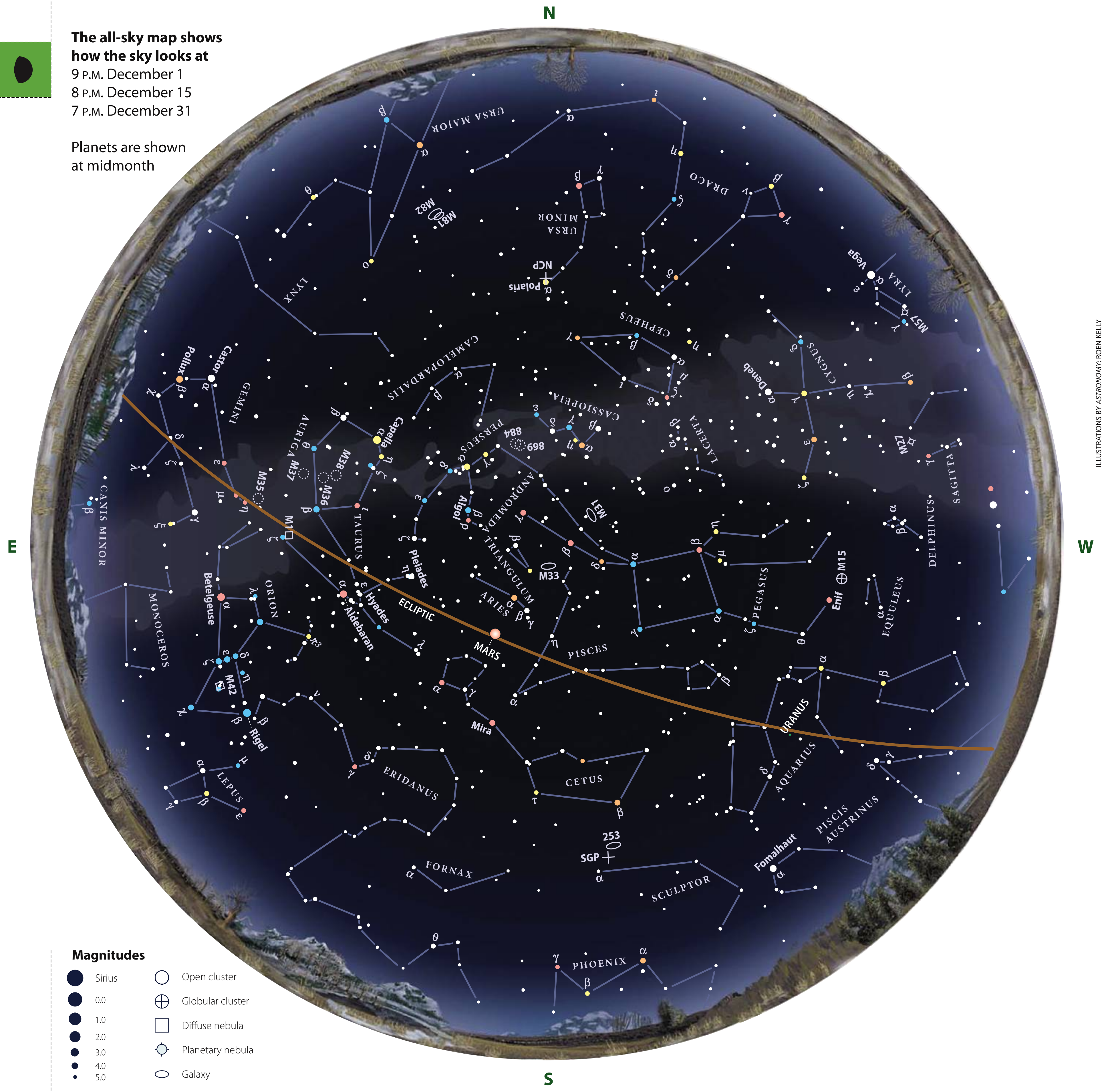
Arrows and dots show planets' positions during the month.


EARTH
Winter solstice is December 21
MARS
VENUS
MERCURY
Greatest western elongation is December 12
JUPITER


SATURN
JUPITER
URANUS
NEPTUNE
PLUTO
Solar conjunction is December 15/16

The all-sky map shows how the sky looks at
9 P.M. December 1
8 P.M. December 15
7 P.M. December 31

Planets are shown at midmonth


N
E
W
S
URSA MAJOR
M81
M82
URSA MINOR
NCP
Polaris
DRACO
LYNX
CEPHEUS
Vega
LYRA
M57
CAMELOPARDALIS
CYGNUS
Deneb
CASSIOPEIA
Castor
Pollux
GEMINI
AURIGA
Capella
M37
M38
M36
M35
PERSEUS
869
884
LACERTA
M27
SAGITTA
DELPHINUS
CANIS MINOR
M1
Algol
ANDROMEDA
M31
TAURUS
Pleiades
TRIANGULUM
M33
PEGASUS
Enif
M15
EQUULEUS
Betelgeuse
ORION
MONOCEROS
Aldebaran
Hyades
ECLIPTIC
ARIES
MARS
PISCES
M42
Rigel
Mira
URANUS
ERIDANUS
CETUS
AQUARIUS
LEPUS
PISCIS AUSTRINUS
Fomalhaut
253
SGP
FORNAX
SCULPTOR
PHOENIX

Magnitudes

●	Sirius
●	0.0
●	1.0
●	2.0
●	3.0
•	4.0
•	5.0

○ Open cluster
⊕ Globular cluster
☐ Diffuse nebula
⌖ Planetary nebula
⬭ Galaxy

This map portrays the sky as seen near 35° north latitude at times shown in the upper left corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

december 05

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
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[25]	[26]	[27]	[28]	[29]	[30]	[31]

ILLUSTRATIONS BY ASTRONOMY: ROEN KELLY

01 New Moon is at 10:01 A.M. EST

04 The Moon passes 2° south of Venus, 1 P.M. EST

The Moon is at perigee (228,270 miles from Earth), 11:33 P.M. EST

08 First Quarter Moon is at 4:36 A.M. EST

09 Asteroid Juno is at opposition, 3 A.M. EST

Venus is at greatest brilliancy (magnitude –4.6), 8 A.M. EST

11 The Moon passes 1.3° north of Mars, midnight EST

12 Mercury is at greatest western elongation (21°), 8 A.M. EST

13 Geminid meteor shower peaks

15 Full Moon is at 11:15 A.M. EST

15 Pluto is in conjunction with the Sun, 11 P.M. EST

19 The Moon passes 4° north of Saturn, 4 A.M. EST

20 The Moon is at apogee (251,664 miles from Earth), 9:49 P.M. EST

21 Winter solstice is at 1:35 P.M. EST

23 Last Quarter Moon is at 2:36 P.M. EST

25 The Moon passes 0.9° north of Spica, 9 A.M. EST

26 The Moon passes 4° south of Jupiter, 11 P.M. EST

28 The Moon passes 0.2° north of Antares, 9 P.M. EST

29 The Moon passes 5° south of Mercury, 7 P.M. EST

30 New Moon is at 10:12 P.M. EST

ONLINE EXTRA For definitions of terms, visit www.astronomy.com/glossary

THE DEEP SKY

The Demon Star Algol winks at us during the height of the Geminid meteor shower. To see a collection of non-shooting stars, visit Perseus' grand cluster, M34.

Fading on cue

Known to the ancients for its odd behavior, the Demon Star Algol in the constellation Perseus dims by 70 percent during the course of a few hours, then recovers as if nothing happened. When English amateur astronomer John Goodricke put it under close scrutiny in the 1780s, he lifted Algol's veil of mystery. Goodricke even suggested — correctly, it turns out — the clockwork variations are caused by a fainter star eclipsing a brighter one. Once each orbit of this eclipsing binary system, the dim companion passes between the main star and Earth, blocking most of the bright star from view.

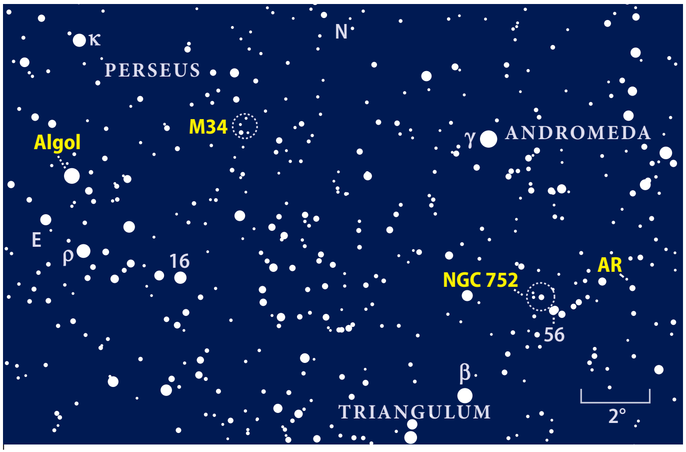
By cosmic coincidence, Algol will dim while Geminid meteors fly. Algol begins the night of December 13/14 at its normal brightness of magnitude 2.1. It starts fading by 11 P.M. EST and reaches minimum brightness (magnitude 3.4) about 1:20 A.M. EST. It then brightens just as quickly, returning to near normal during the next 2 hours. Although Algol takes nearly 10 hours to complete an eclipse, most of the brightness change happens in the middle 4 hours.

The Demon Star's next act will be easier for evening observers to follow. It takes place between approximately 8 P.M. and midnight EST December 16, with minimum occurring at 10:09 P.M.

One way to remember which star is Algol, is to imagine it as the end of the handle in a "Giant Dipper" asterism. In this view, the Great Square of Pegasus serves as the bowl and Andromeda's southern string of stars forms the rest of the handle. Algol normally shines as bright as any of them, but at its dimmest, it is easily the faintest of the lot.

JACK NEWTON

GLITTERING STAR CLUSTER M34 lies on the outskirts of the Milky Way. You can spot it with the naked eye under a dark sky.



ASTRONOMY: ROEN KELLY

THE HERO PERSEUS rides the Milky Way, giving it a complement of bright star clusters as well as a famous variable star, Algol.

City clusters

It's pretty tough for the diffuse light of a distant galaxy or nearby comet to shine through the skyglow that pervades most populated areas. Not so with star clusters. These collections of stellar pinpoints penetrate the veil with relative ease.

The 34th entry in Charles Messier's catalog of clusters and nebulae proves the point. Look for it near the end of our imaginary dipper's handle. From a city backyard, binoculars will show you M34 clearly; a telescope, with its higher magnification, frames it nicely.

A much different cluster, NGC 752, lies not far away in Andromeda. Slightly bigger than M34, NGC 752 comprises stars mostly of the same brightness. Just off the cluster's southwestern edge lies a wide pair of orange stars cataloged as 56 Andromedae. These stars are foreground objects unrelated to the cluster. If you're away from the city, NGC 752 shows up nicely in binoculars.

What a blast

A short, 2.5° hop west from NGC 752 will land you on the unpredictable variable star AR Andromedae. When you first look for it, you may see an 11th-magnitude star — or nothing at all. In its quiescent phase, AR And simmers at 17th magnitude, slowly pulling gas from its faint, bloated companion star. After 15 or 20 days, enough fuel builds up to create a runaway thermonuclear explosion, catapulting the system's brightness more than a hundredfold for a few nights. Astronomers call such stars cataclysmic variables.

Martin Ratcliffe *is the former president of the International Planetarium Society.* **Alister Ling** *is a meteorologist for Environment Canada.*

THE PLANETS

Venus dazzles viewers around the world from its perch low in the early evening sky, while Mars and Saturn remain prominent nearly the whole night through.

Shining brilliantly in the southwestern sky after sunset, **Venus** will immediately grab your attention. It reaches greatest brilliancy December 9, when it gleams at magnitude –4.6, but it remains the brightest point of light in the sky all month.

Venus' appearance through a telescope shows a remarkable range this month. On the 1st, the planet appears 36" across and 33-percent lit. By New Year's Eve, it measures 57" across and shows a 7-percent-lit phase. It shouldn't take you long to realize Venus' orbital motion is bringing the planet closer to us while its sunlit hemisphere rotates away.

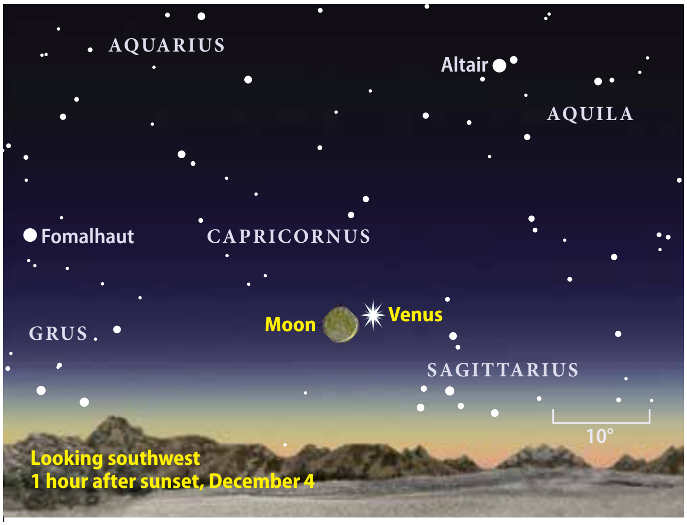
Don't miss the view December 4, when a crescent Moon stands 4° to Venus' left. The Moon then appears 15-percent lit, about half the planet's illumination. Try this trick to compare the two crescents directly: With your right eye, view Venus through a scope; at the same time try to view the Moon with your left eye. This will work only with a refractor or small Schmidt-Cassegrain telescope, where you view along the direction the instrument points.

Before turning your gaze to Mars, the next brightest planet in the sky, take a few minutes to hunt down Neptune and Uranus before they disappear. **Neptune** glows at magnitude 8.0, bright enough to see through binoculars. It lies near the 4th-magnitude star Theta (θ) Capricorni. Try to catch the planet in early December. By the end of the month, it will be hard to pick out through the early evening haze.

Uranus lies higher in the sky than Neptune, among the background stars of Aquarius. At magnitude 5.9, it's an easy target through binoculars. You'll find it about halfway along an imaginary line joining Sigma (σ) and Lambda (λ) Aquarii. Look for it early in the evening — haze near the horizon will render it invisible well before its 10 P.M. setting time.

Let's turn now to **Mars**. The Red Planet remains high on the observing list this month even as it continues to fade and shrink. On December 1, it shines at magnitude –1.6, still brighter than the brightest star in the sky, Sirius. It dims a full magnitude during the course of the month.

Through a telescope, the best views will come in the first half of December, when the planet's disk spans 15" or more. By month's end, its apparent diameter is down to 12", making it harder to see fine surface detail through small scopes. Mars stands high in the southeast after darkness falls, placed perfectly for early evening observers. Its high altitude yields crisp views because the planet's light doesn't have to travel through as much of Earth's turbulent atmosphere.



ASTRONOMY: ROEN KELLY

VENUS APPEARS BRIGHTEST during December, but the highlight of its month comes when the Moon scoots by on the 4th.

As soon as darkness falls December 1, the Red Planet's most prominent dark feature, Syrtis Major, lies centered on the martian disk. Because Mars takes about 40 minutes longer to rotate than Earth does, if you view at the same time from one night to the next, specific martian features appear slightly farther east. By December 7, Syrtis Major is just coming around the planet's eastern limb as the sky grows dark. During the first 3 hours of darkness, this dark feature rotates into view and returns to the disk's center once again.

By mid-December, Mare Sirenum lies at the center of the martian globe in the early evening. Late in the month, Solis Lacus, the dark feature known as the "Eye of Mars," stands front and center in the early evening hours. In addition to Mars' light and dark surface markings, look for a less-than-full phase by month's end. On New Year's Eve, the planet's disk appears 92-percent illuminated and noticeably out-of-round.

DAVID BREWER

A BIG, CRESCENT VENUS greets anyone who aims a telescope at the brilliant planet this month.

You don't need a telescope to watch Mars move across the sky. Or, more precisely, to see it stop moving. On December 10, Mars' retrograde motion comes to a halt, and it resumes its eastward trek relative to the stars of Aries the Ram.

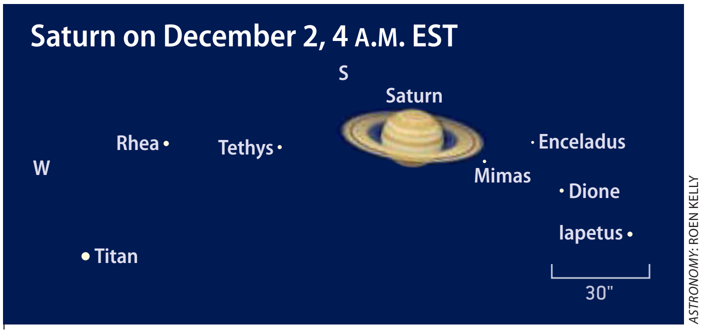
Soon after darkness falls, **Saturn** puts on a nice display. By 11 P.M. local time December 1, it stands 20° high in the east. At the end of the month, you'll find it well clear of the horizon by 9 P.M. local time. The ringed planet brightens throughout December, reaching magnitude –0.1 at year's end. It lies among the faint background stars of Cancer the Crab. A quick binocular scan of this region will reveal the eye-catching Beehive star cluster (M44) northwest of Saturn. A waning gibbous Moon passes 4° north of the planet December 18.

Saturn ranks among the best telescopic sights in the sky. The rings show up nicely in any scope. Most viewers can spot the Cassini Division, the dark gap that separates the outer A ring from the brighter B ring. This month, the rings span 45". The planet's globe measures 20" across, although few features are visible in its haze-laden atmosphere. The view of Saturn improves as it climbs higher in the sky after midnight. Its light then passes through less of our atmosphere, so you can use higher magnifications with greater success.

Tracking the motions of Saturn's moons can keep you entertained almost every night. Each scoots around the planet with a different period. Occasionally, this brings about curious alignments.

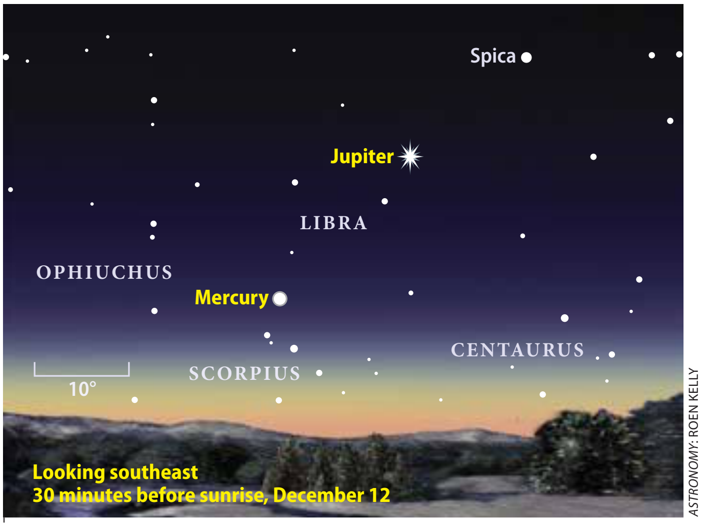
A good example comes December 1 and 2, when all the planet's bright moons cluster near Saturn's disk. This includes Titan and Iapetus, two moons that spend most of their time far from the planet. Through a telescope, 8th-magnitude Titan appears brightest. Iapetus is more intriguing visually, however, because it has a dual personality. When it lies west of the planet, Iapetus shows us its brighter face, glowing at 10th magnitude. The moon appears 2 magnitudes fainter when it's east of Saturn and its dark side faces us. Iapetus grows brighter through most of December, as it moves toward western elongation on the 22nd.

Giant **Jupiter** appears conspicuous shortly before dawn. It shines at magnitude –1.8, making it the brightest object by far in the eastern sky. Jupiter spends all month among the stars of Libra the Scales, edging closer to that constellation's brightest star, Zubenelgenubi. On the 31st, Jupiter lies 2° northwest of the star.



ASTRONOMY: ROEN KELLY

SATURN'S BRIGHT MOONS all gather near the planet during the early morning hours of December 2.



ASTRONOMY: ROEN KELLY

MERCURY'S BEST APPEARANCE of the year comes in December's morning sky. Use brilliant Jupiter as a guide to the inner planet.

Small telescopes will show Jupiter's four bright moons: Io, Europa, Ganymede, and Callisto. You'll probably want to wait a month to get a good view of the planet's disk, however. Jupiter will then stand higher in the sky as twilight begins.

Mercury makes its best appearance of the year in December's morning sky. When it reaches greatest western elongation December 12, the planet rises nearly 2 hours before the Sun and stands 12° above the southeastern horizon 30 minutes before sunrise.

You can spot Mercury to the lower left of Jupiter. How far below depends on when you look. At greatest elongation, the innermost planet lies at half Jupiter's elevation half an hour before sunrise. On December 20, Mercury passes 6° north of Antares. At magnitude –0.6, Mercury appears much brighter than the 1st-magnitude star.

Through a telescope, the small planet puts on a good show during December. It begins the month sporting a 9.0"-diameter disk that's just 16-percent lit. At greatest elongation, it appears 6.6" across and 63-percent illuminated. By month's end, the planet's disk is down to 5.1" in diameter and the phase is up to 91-percent lit.

A Christmas gift greets early risers December 25, when the Moon hides the bright star Spica from view. This lunar occultation takes place during twilight for observers northeast of a line that stretches from Seattle to near Texas' border with Mexico. Observers southwest of this line won't witness an occultation, but they will see a pretty scene with the Moon passing just above the star. The event takes place in daylight for most observers. To find the exact time of the event for your location, visit www.lunar_occultations.com.

The winter solstice occurs December 21 at 1:35 P.M. EST. This marks the moment when the Sun lies at its farthest point south of the celestial equator, and the Northern Hemisphere experiences its shortest day.

METEORS AND MOONS

The month's two best meteor showers battle a bright Moon, but observers should still give the Geminids and Ursids a chance to shine.

A not-so-sparkling gem

One of the best annual meteor showers won't live up to its billing this year. The Geminid shower reaches its peak the night of December 13/14 — just 1 day before Full Moon. The Moon's bright glow will wash out fainter meteors, leaving observers to see just the bright ones.

Fortunately, this shower can stand the interference better than most. Geminid meteors tend to be bright, so a higher percentage will shine through the Moon's unwanted glow. And more Geminids show color than any other shower except the Perseids. Expect to see about 10 meteors per hour from a city or suburban location, more if you're out in the country. The meteors appear to radiate from the constellation Gemini, but they can blaze across any part of the sky.

One trick to try: Position yourself with your back to the Moon and a building or tree blocking the Moon's disk. This will make your sky appear darker and yield more meteor sightings. And as with any extended observing this time of year, dress warmly and in layers. If you get cold, head inside for 10 minutes and grab some hot coffee or tea.

The Bear's shower

The Moon also interferes with December's second meteor shower, although not as badly. The Ursid shower peaks the morning of December 22, when a waning gibbous Moon lights up the sky. The radiant lies near the bright star Kochab (Beta [β] Ursae Minoris), which appears below Polaris in the evening and above it before dawn.

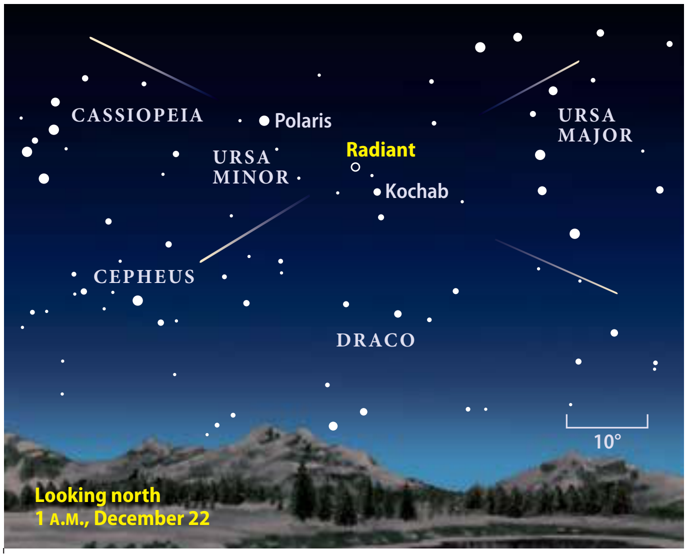
If 2005 is a typical year, count yourself lucky if you spot more than 5 meteors per hour. Ursid outbursts have occurred, however, so it may pay to watch. In 1988, 1994, and 2000, peak rates reached at least 3 times normal.

A shepherd's crater

Shortly after the crescent Moon appears in the evening sky, the crater Endymion becomes visible near the northeastern limb. Named for a beautiful young shepherd in Greek legend, Endymion lies between the lunar limb and a prominent crater pair, Atlas and Hercules, beyond the eastern shore of Mare Frigoris.

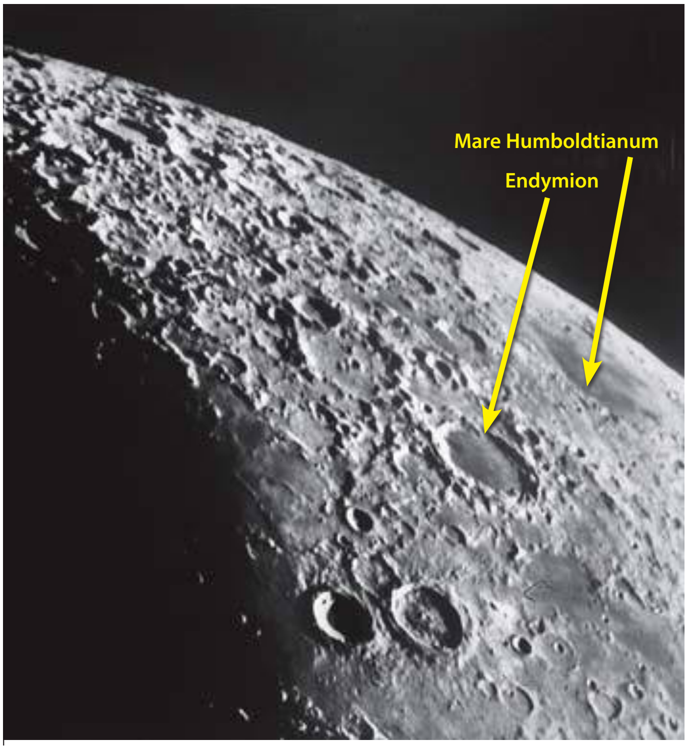
Endymion is a large crater measuring 77 miles across. Its floor appears smooth and dark, with a few bright patches. The crater's walls, highest on the northern side, reach more than 2 miles above the floor.

The Moon's northeastern limb shows up best in early December, from around the 3rd to the 8th. A favorable libration enhances the view by tilting this region slightly in our direction. This makes a good time to look for Mare Humboldtianum, an elusive dark expanse even closer to the limb.



ASTRONOMY: ROEN KELLY

THE URSID METEOR SHOWER peaks December 22, but a waning gibbous Moon will reduce the number of shooting stars visible.



FROM CONSOLIDATED LUNAR ATLAS (LPL/UA)

LUNAR CRATER ENDYMION lies near the Moon's northeastern limb, where it comes into prominence a few days after New Moon.

COMETS AND ASTEROIDS

Asteroid Vesta cruises past the Eskimo Nebula and two bright stars this month. You'll need more patience and a darker sky to spot Comet C/2005 E2 (McNaught).

Vesta rocks

December offers an exceptional opportunity to find an interplanetary rock. Not only is 4 Vesta the brightest asteroid in the sky, it also crosses the bright star fields of Gemini the Twins, which provide plenty of visual clues to help you track down this minor planet.

Head outside after 8 P.M. or so, and look to the east to find Castor and Pollux, Gemini's two brightest stars. In early December, Vesta lies almost halfway from Castor (the northernmost member of the pair) to the bright yellow star Procyon in Canis Minor. At month's end, the asteroid appears nearly one-third of the way from Pollux to Orion's ruddy luminary, Betelgeuse.

Vesta glows at 7th magnitude this month, bright enough to see it through binoculars even from the suburbs. Only a handful of background stars in this part of Gemini have a similar brightness, so picking out the 320-mile-wide rock should be easy.

Vesta has a few close calls with more distant objects this month, which should make finding it even easier. On December 13, the asteroid sails 11' (one-third the Moon's apparent diameter) north of the Eskimo Nebula (NGC 2392). This 9th-magnitude planetary nebula makes a fitting companion for a cold December night. Two nights later, Vesta tracks 12' south of the 5.2-magnitude star 63 Geminorum. And finally, December 24, the asteroid skims 6' south of the 3.5-magnitude star Delta (δ) Gem.

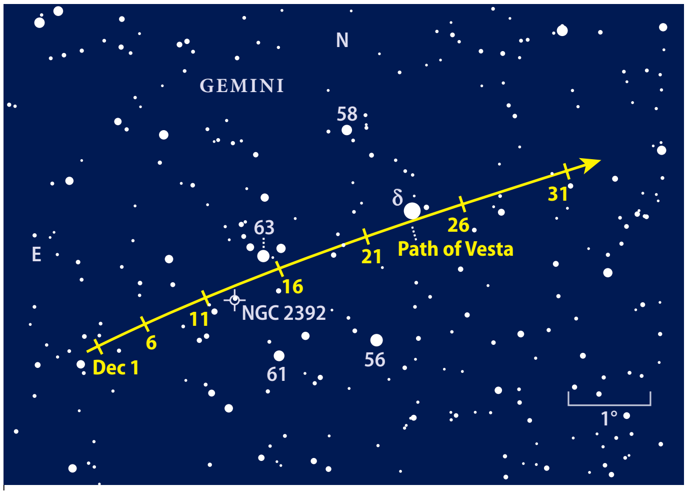
At the start of the 19th century, astronomers discovered asteroids by noticing a star out of place among the cataloged ones. In the days before cameras and computers, this was a tough slog. German astronomer Heinrich Olbers first sighted Vesta, the fourth minor planet, March 29, 1807; the 5th asteroid wasn't found until 1845.

Catch Comet McNaught

In comparison with asteroids, moderately bright comets were easy to find in the 19th century. Their large, diffuse shapes and relatively fast motion were a dead giveaway to astronomers unburdened by the light pollution we face today.

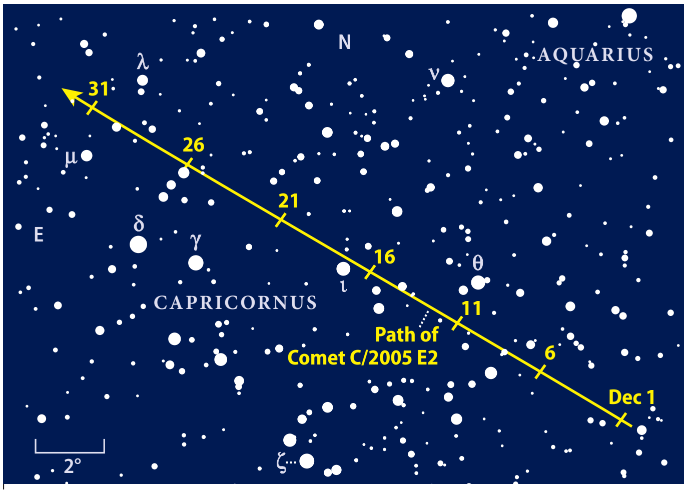
You can test your observing skills by shooting for a 10th-magnitude comet, C/2005 E2 (McNaught). It lies in Capricornus, near the line of four bright stars that forms the eastern end of the constellation's pattern. It passes less than a degree north of 4th-magnitude Iota (ι) Cap December 17.

The comet sets around 9 P.M. this month, so you'll need to get out early if you want to spot it. Skyglow will conceal this primordial snowball, so find a dark-sky location and avoid the Moon: Your hunt should take place before December 5 or after the 18th.



ASTRONOMY: ROEN KELLY

ASTEROID 4 VESTA glows at 7th magnitude among the background stars of Gemini the Twins. Watch it pass the Eskimo Nebula (NGC 2392) December 12.



ASTRONOMY: ROEN KELLY

COMET C/2005 E2 (McNAUGHT) should glow around 10th magnitude this month as it slowly tracks northeastward across the zodiacal constellation Capricornus.

Comet McNaught will remain in the early evening sky for the next 3 months. Both the comet and Earth are going around the Sun in the same direction (counterclockwise as viewed from north of the solar system), and Earth's moving only a little faster on the inside track. It's all in the timing. If the comet had arrived in the inner solar system just 3 months ago, we would have seen it some 3 magnitudes brighter.

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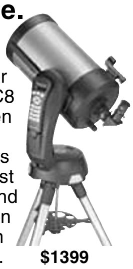
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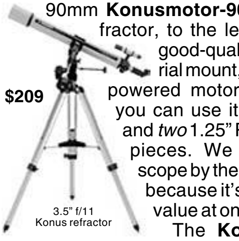
The scope has a modern anodized version of Celestron's vintage orange and black paint, a convenient go-to computer with no-guesswork *SkyAlign* technology, and the bright images of Celestron's best Starbright XLT multicoatings.

The most amazing part? This 21st century telescope is available for less than the price of a C8 from 1984 that didn't even have a computer.

Amateur astronomy has changed a lot over the past 20 years. But the value and performance of a Celestron C8 have always been standards you can rely on.

Are these great values? You bet they are.


$209

3.5" f/11 Konus refractor

$499

8" f/5 Konus reflector

6" f/12 Konus Maksutov

$799

The low prices of these **Konus** telescopes are downright amazing.

Consider the optically very nice 90mm **Konusmotor-90** f/11 refractor, to the left. It has a good-quality equatorial mount, a battery-powered motor drive so you can use it anywhere, and *two* 1.25" Plössl eyepieces. We sell this scope by the dozens, because it's a great value at only $209!

The **Konusky-200** 8" f/5 reflector, above right, has a heavy duty equatorial mount with a steel leg tripod, *dual-axis* DC motor drives, *two* 1.25" Plössl eyepieces, an 8 x 50mm finderscope, and a polar axis finder. It's a lot of telescope for the low price of only $499!

The **Motormax-150** 6" Maksutov, to the right, has the same heavy duty mount and accessories as the 8" reflector.

It's a terrific value at its low price of only $799, which is well below the cost of other large Maksutovs.

New 8", 10", and 12" Meade LX90-LNT scopes *in stock.*

Meade 8" LX90-LNT

$1799

freight paid

The popular **Meade LX90-LNT** 8" go-to Schmidt-Cassegrains now have 10" and 12" big brothers. All LX90 scopes ship from our stock, so we save you shipping time over dealers who must have them drop-shipped from Meade (and if you're in California, we save you the sales tax).

Here are the *freight-paid* prices on the LX90's shipped from our stock:

8" LX90-LNT	**$\$1799^{00}$**
8" LX90-LNT, w/UHTC	**1974^{00}**
10" LX90-LNT	**2299^{00}**
10" LX90-LNT, w/UHTC	**2474^{00}**
12" LX90-LNT	**2999^{00}**
12" LX90-LNT, w/UHTC	**3294^{00}**

Level North Technology makes it easier than ever before to line up your scope on the sky and start observing. Simply tell your LX90-LNT your location *or zip code.* It levels its optical tube by itself, aims it North, checks the time, then moves to its two alignment stars – *all automatically!* Center the red dot finder on the alignment stars (you also get an 8 x 50mm finder), and start enjoying go-to computerized observing. An LX90-LNT is an *easy* scope to use, and now it comes in large economy sizes!

A 6" go-to SCT for $999. Now, *that's* a good deal.

$999

The **Celestron Advanced Series** 6" Schmidt-Cassegrain gathers 44% more light than a more expensive 5" Maksutov to show you more faint objects, with 20% higher resolution. Its faster f/ratio means a wider field and brighter images, too.

It has an adjustable height tripod with 2" steel legs, heavy-duty equatorial mount, dual motor drives, Starbright XLT multicoatings, eyepiece, finder, and a NexStar computer to find and track over 45,000 stars and objects for you *automatically.*

No-guesswork Celestron *GPS* Schmidt-Cassegrains.

Celestron 8" f/10 CPC800

$1899

It's easy to find your way around the sky with a new **Celestron CPC**. Just point it at any three of the 50 brightest lights in the sky (3 stars, or 2 stars and a planet or the Moon) and the CPC will find over 45,000 fascinating deep space objects for you at the touch of a button.

You don't have to memorize a star chart to use a CPC. The scope's built-in GPS system and a few anonymous points of light in the sky are all you need.

Celestron CPC Schmidt-Cassegrains are fully equipped with all the features you need to start observing immediately.

8" **CPC800**, Starbright coatings	**$\$1899^{00}$**
8" **CPC800X**, XLT coatings	**1999^{00}**
9¼" **CPC925**, Starbright coatings	**2349^{00}**
9¼" **CPC925X**, XLT coatings	**2499^{00}**
11" **CPC1100**, Starbright coatings	**2599^{00}**
11" **CPC1100X**, XLT coatings	**2799^{00}**

A TeleVue cash rebate direct to you . . .

From now through December 31, 2005, you can get a $25 check direct from TeleVue each time you buy one of the following:

Mars A and B filter set	$230
2.5mm, 3.5mm, 5mm, 7mm, or 9mm Nagler Type 6	$280 each
2mm-4mm Nagler zoom	$395
3mm-6mm Nagler zoom	$380
3mm, 4mm, 5mm, 6mm, 8mm, or 10mm Radian	$240 each
8/11/15mm Plössl set	$246

You get a $25 check from TeleVue for each item you buy (up to a limit of two of any single model). We'll send a form with your purchase for you to fill out and send to TeleVue to claim your rebate check.

We actually stock TeleVue. Does your dealer?

NP-101 **$3595**

Others may *say* they carry **TeleVue** telescopes, *but we actually keep TeleVue scopes in stock.* Dozens of them.

A few of the TeleVue scopes we have in stock for immediate shipment are listed below. These are optical tubes only, with dust covers and carrying case.

TV-60, 2.4" f/6 apo	**$\$795^{00}$**
TV-76, 3" f/6.3 apo	**1275^{00}**
TV-85, 3.35" f/7 apo	**1680^{00}**
TV-102, 4" f/8.6 apo	**2200^{00}**

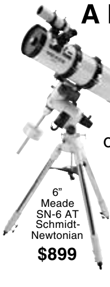
The following scope packages (for use on your own mount) with a star diagonal, Plössl eyepiece, tube ring, dust covers, and case, are also in stock.

TV-76, 3" f/6.3 apo	**$\$1675^{00}$**
TV-85, 3.35" f/7 apo	**2080^{00}**
TV-102, 4" f/8.6 apo	**2635^{00}**
Renaissance, 4" f/8.6 brass	**2935^{00}**
NP-101, 4" f/5.4 Petzval apo	**3595^{00}**

And we stock all TeleVue eyepieces and accessories for immediate shipment.

> I just wanted you to know that I received my order only 2 days after it was shipped; shipped the same day it was ordered! I am extremely impressed by your service, and your awesome shipping department. You have a grateful customer in me...
>
> **Customer Quote of the Month #165**

A Meade LXD75 go-to makes astronomy easy.


6" Meade SN-6 AT Schmidt-Newtonian

$899

8" Meade SC-8 AT Schmidt-Cassegrain

$1399

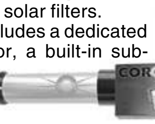
You won't spend all of your time hunting for celestial wonders with a go-to computerized **Meade LXD75** reflector, refractor, or Schmidt-Cassegrain.

A few touches on the Autostar computer and your LXD-75 speeds you to any of more than 30,000 stars, planets, and deep space objects, then tracks it for as long as you want to observe. You spend more of your time looking *at* celestial objects and less time looking *for* them with a Meade LXD75.

Each has an adjustable height steel leg tripod, dual battery-operated motor drives, finderscope, eyepiece, illuminated polar finder, and an Autostar go-to computer.

Want to read *unbiased* equipment reviews? www.cloudynights.com

Serious solar observing for the price of an eyepiece!



$499

For no more than cost of a premium eyepiece, the sub-Ångstrom hydrogen alpha filter in the **Coronado PST** (Personal Solar Telescope) lets you see the ever-changing drama of solar flares and prominences growing and subsiding before your eyes. It doesn't just show you sunspots, as do ordinary solar filters.

The PST includes a dedicated 60mm refractor, a built-in sub-Ångstrom solar filter, a safe Sun finder, and a 1.25" eyepiece.

Celestron *SkyAlign* go-to scopes start at a low $279.

$379

80mm Celestron NexStar 80 SLT

You don't need to know the Pleiades from Polaris to find your way around the sky with a **Celestron SLT** go-to scope. With Celestron *SkyAlign* technology, just point your SLT at any three of the 50 brightest lights in the sky (3 stars, or 2 stars and a planet), and the SLT will find the planets and over 4,000 deep space objects for you *automatically.* A few anonymous points of light are all you need to find your way around the skies.

Celestron SLT no-guesswork go-to scopes are available in these sizes:

NexStar 60, 60mm refractor	**$\$279^{00}$**
NexStar 80, 80mm refractor	**379^{00}**
NexStar 102, 102mm refractor	**479^{00}**
NexStar 114, 114mm reflector	**399^{00}**
NexStar 130, 130mm reflector	**439^{00}**

Each has *two* eyepieces, red dot finder, motor drives, stainless steel tripod, NexStar computer, software to control the scope from your computer, and more.

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A super selection of affordable holidays gifts from \$2^{49} to $200 . . . *for giving or getting!*

Here's a tasty smorgasbord of observing aids that are sure to please any astronomer. Give one or more to your favorite observer or leave a copy of this ad on the kitchen table with the items *you* hunger for this year neatly circled in red. Santa is bound to notice your subtle hint.

Gifts under $50 . . .

Eyepiece cases start at only $2.49. Our seven bolt-type plastic containers keep your eyepieces and filters free from dew and dust. Foam inserts cradle eyepieces to protect against accidents. **www.astronomics.com** lists the eyepieces that fit each container.

Show your colors (as long as they're blue and white) for $12.95! Astronomics T-shirts are preshrunk 100% cotton in midnight blue. They fit adult sizes L, XL, 2XL, and 3XL. The Astronomics logo is on the front. There's a glow-in-the-dark map on the back showing the location of The Optical Center of the Known Universe™.

Observing books at one-third their regular price.

Stars & Galaxies: Our part #A9566. This 200-page hard cover includes 344 of the most fascinating deep sky objects for scopes of all sizes. Regularly $29.95, it's sale priced at only **$9.95.**

Galaxies & The Universe: This 112-page soft cover helps you find hundreds of galaxies with scopes 8" and larger. Our part #A9573. Regularly $19.95, it's sale priced at only **$6.50.**

Universe From Your Backyard: This 188-page hard cover, #A9565, helps you find 690 amazing deep space objects with scopes of all sizes. Regularly $29.95, it's on sale for only **$9.95.**

LED flashlights start at only $19.95. Red LED night vision flashlights protect your dark-adapted vision while you're observing. The **Celestron** variable brightness flashlight (our part #VLED) is **$19.95**. The **Rigel Systems** variable brightness light (#4591), right, is **$24.95.** The **Rigel Systems** two-color variable brightness flashlight (#4592) – a red light for reading star charts, and blue-white for setting up and taking down your scope – is **$29.95.**

The best CCD book is $49.95. Before you spend $3000 on a CCD camera (or even $99), spend **$49.95** on this very informative book. **The New CCD Astronomy** by Ron Wodaski is the best and most complete imaging reference available for CCD photographers of all skill levels. It includes everything you need to know to become proficient at CCD imaging, plus a free subscription to on-line updates and reference materials.

Vibration suppression pads stop your scope's jitters. Put these handy pads under the legs of your telescope or spotting scope tripod and you'll virtually end the tremors that blur your view for a few seconds each time a breeze comes up or you touch the scope to focus. A set of three **Celestron** vibration suppression pads, our part #VSP, costs **$49.50.** The set of three **Meade** vibration isolation pads to the right, our part #895, costs **$49.95.** Both sets will improve your observing and are well worth the modest investment.

Gifts from $50 to $100 . . .

Power to the people! Buy one Power Tank instead of hundreds of flashlight batteries. **Celestron Power Tank** high capacity rechargeable batteries have the power you need to run your scope and accessories all night long. They can be recharged hundreds of times – and that will save you hundreds of dollars over the cost of buying flashlight batteries every few weeks.

Each has *two* 12V DC cigarette lighter outputs; 3, 6, and 9V DC outputs for accessories; an emergency spotlight; built-in recharger; shoulder strap; carry handle; and more. The 7 amp hour Power Tank to the right, our part #4512V, is only **$59.95**. The 17 amp hour capacity Power Tank, our #4517V, is sale priced at only **$89.95**.

You can picture the planets for $99. There's a real CCD camera in the **Celestron NexImage** Solar System Imager. It's a Sony HAD (Hole Accumulation Diode) full color CCD with an array of 640 x 480 5.4 micron pixels.

The NexImage takes high magnification Moon and planet images with any scope and sends them to your computer to view live or print out later.

If you want to add a useful accessory to the NexImage camera, consider the NexImage Reducer Lens at $24.50. It doubles the field of view for wider lunar panoramas. Another accessory to consider is the $57.95 NexImage 1.25" UV/IR filter. It gives sharper planetary surface detail with *all* CCD cameras.

Gifts from $100 to $200 . . .

The sky is yours for $129! Well, it's not actually the real sky, but rather the **TheSky6 *Serious Astronomer Edition*** from **Software Bisque**. It's the latest version of the most popular star-charting software around. With over 20 million stars and over a million deep space objects in its database, it generates the most realistic and detailed graphical rendition of the night sky ever. It looks so real you'll think you're under the stars themselves.

Get more diagonal. Pay less money. How much would you pay for a 1/10th wave accuracy 97% reflectivity 2" enhanced aluminum mirror star diagonal and a 1.25" eyepiece adapter? Some competitors charge up to $250 for that combination. But the **William Optics** 2" enhanced aluminum diagonal, our part #W2, is only **$130**!

A competitor charges $345 for a 2" diagonal with a 30-layer dielectric mirror for 99% reflectivity. The William Optics 2" dielectric diagonal, our part #W2D, costs only **$198**!

The **William Optics** 2" rotatable Schmidt-Cassegrain zero image shift Crayford-style manual focuser with 1.25" eyepiece adapter below, our part #WSCTF, is only **$150**. As with all William Optics scopes and accessories, it offers exceptional value – fine optical performance and quality mechanics, at a price that's less than the competition.

Why look at a map when you can look at the sky? When skies are cloudy, you can spend your next evening's observing with the help of a star chart – or you can use **The Desktop Universe** from **Main Sequence Software**. This **$199.95** software program was named the leading Hot New Product by *Sky & Telescope* magazine. While it has all the standard star-charting features of a state-of-the-art planetarium program, it plots your charts on a seamless all-sky photographic CCD mosaic of nearly 20,000 images. You don't see lines and symbols on a blank page. You see the actual sky itself. *Sky & Tel* suggested, "It just might be the biggest advance in portraying the night sky since the paintings on the ceilings of Egyptian tombs."

A binoviewer with eyepieces for $199. Other binocular viewers for an SCT can cost over $1200 – without eyepieces. The **Burgess Optical** Binoviewer costs only $199, *including* two eyepieces. View with two eyes through the Binoviewer's multi-coated BaK-4 prisms and you'll see up to 40% more detail than you see through a single eyepiece in the same scope.

Designing a binoviewer isn't rocket science, and modern CNC computerized manufacturing makes this one both good *and* inexpensive. We've sold over 400 of these to very happy buyers. Try one and see the 40% of the detail *you've* been missing.

To use the Binoviewer with a refractor or reflector, add a thread-in Burgess optical corrector Barlow for only $29.

Scopebuggy makes it easy to move your scope.

A **Scopebuggy** telescope transporter has big 10" pneumatic tires, a pivoting front wheel, and a pull handle that make it so easy to move scopes weighing up to 300 lbs. that even a child can do it.

Know your zip code? You can use a Meade Premier ETX.

All you have to do to find your way around the sky with your new 3.5" to 5" **Meade Premier Series ETX** Maksutov-Cassegrain is tell it your zip code.

Patented Meade *Level North Technology* automatically levels the optical tube, finds North, sets the time, and moves to two alignment stars. Simply check to be sure the wide angle red dot finder is centered on those stars. Then tell your ETX which of the 30,000+ objects in its memory you want to see, and the scope takes you there automatically.

It doesn't take a degree in rocket science to use an ETX Premier Series scope. It's almost as simple as simply knowing where you live!

Each Premier ETX comes supplied with a field tripod, red dot finder, 26mm Super Plössl eyepiece, and more.

ETX-125PE
$1099
freight paid

$299 for a Meade Deep Sky Imager.

The **Meade Deep Sky Imager** takes full color photos of galaxies, nebulas, star clusters, the Moon, and planets at a fraction the cost of a CCD camera.

The DSI is a one-pass color camera, so there's no need to take multiple exposures through filters and combine them later to come up with a color image.

The easy-to-use Meade Deep Sky Imager also includes a USB cable and the Autostar Software Suite of imaging control software in its low price of only $299.

A go-to scope only \$209^{95}? Hard to believe.

BUSHNELL

Go-to scopes take the guesswork out of finding your way around the skies. They move your scope *automatically* to the object you want to see, so you find your way around the skies like a veteran – even if you don't know Polaris from the Pleiades.

\$209^{95}
Bushnell
NorthStar 3"
f/9.2 go-to
reflector

The 3" **Bushnell NorthStar 3** go-to reflector has everything you need to get started in astronomy, including *two* eyepieces, a Barlow, a red dot finder, and a talking computer with 20,000 stars and objects to locate for you. Want a great value in a go-to starter scope? Look no further.

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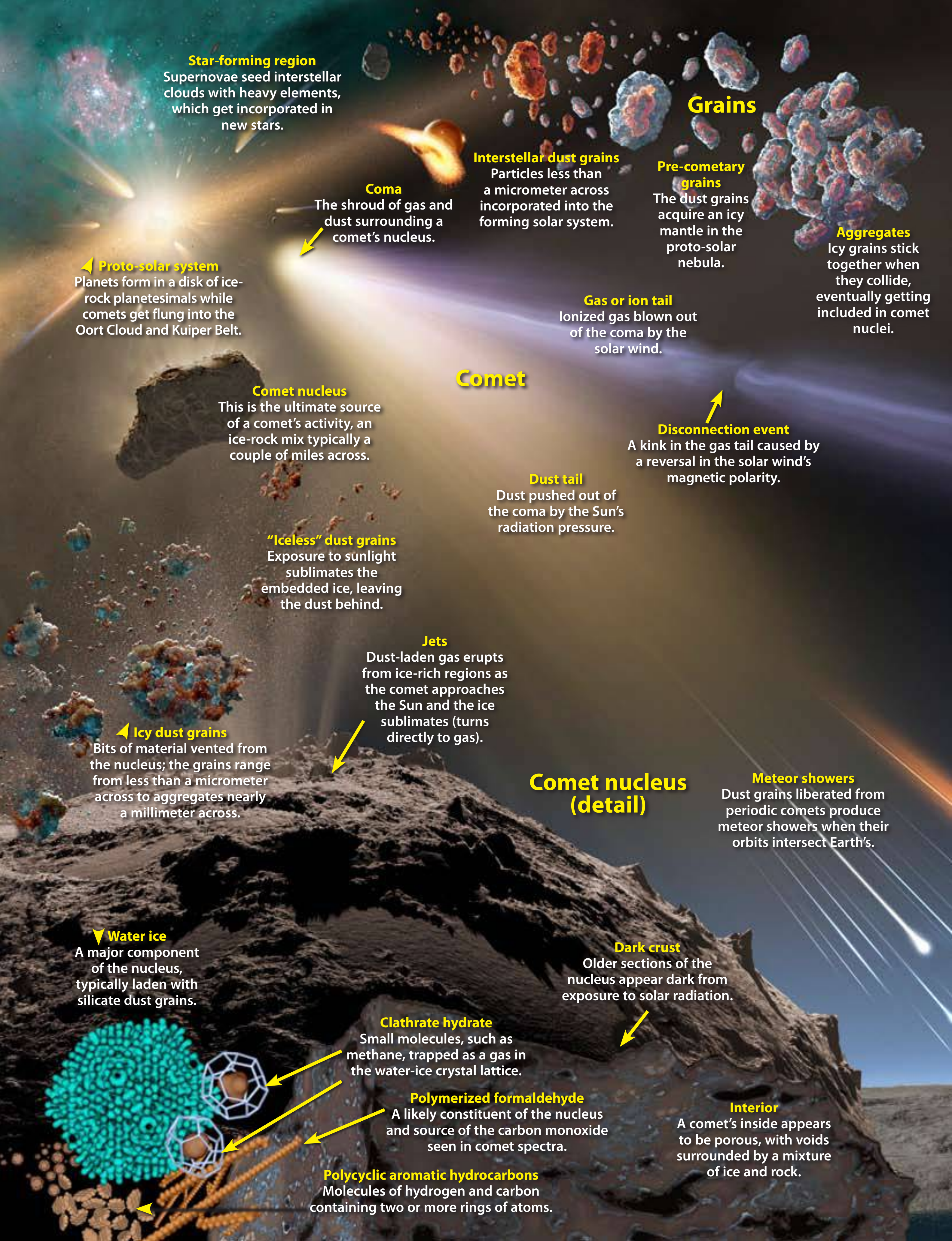
Price match fine print: competitor's price must be verifiable and available nationally; chain store, close-out, and going-out-of-business prices are excluded; no retroactive price matching; a package price must be from a single competitor.



Star-forming region
Supernovae seed interstellar clouds with heavy elements, which get incorporated in new stars.

Grains

Interstellar dust grains
Particles less than a micrometer across incorporated into the forming solar system.

Pre-cometary grains
The dust grains acquire an icy mantle in the proto-solar nebula.

Aggregates
Icy grains stick together when they collide, eventually getting included in comet nuclei.

Coma
The shroud of gas and dust surrounding a comet's nucleus.

Proto-solar system
Planets form in a disk of ice-rock planetesimals while comets get flung into the Oort Cloud and Kuiper Belt.

Gas or ion tail
Ionized gas blown out of the coma by the solar wind.

Comet

Comet nucleus
This is the ultimate source of a comet's activity, an ice-rock mix typically a couple of miles across.

Disconnection event
A kink in the gas tail caused by a reversal in the solar wind's magnetic polarity.

Dust tail
Dust pushed out of the coma by the Sun's radiation pressure.

"Iceless" dust grains
Exposure to sunlight sublimates the embedded ice, leaving the dust behind.

Jets
Dust-laden gas erupts from ice-rich regions as the comet approaches the Sun and the ice sublimates (turns directly to gas).

Icy dust grains
Bits of material vented from the nucleus; the grains range from less than a micrometer across to aggregates nearly a millimeter across.

Comet nucleus (detail)

Meteor showers
Dust grains liberated from periodic comets produce meteor showers when their orbits intersect Earth's.

Water ice
A major component of the nucleus, typically laden with silicate dust grains.

Dark crust
Older sections of the nucleus appear dark from exposure to solar radiation.

Clathrate hydrate
Small molecules, such as methane, trapped as a gas in the water-ice crystal lattice.

Polymerized formaldehyde
A likely constituent of the nucleus and source of the carbon monoxide seen in comet spectra.

Interior
A comet's inside appears to be porous, with voids surrounded by a mixture of ice and rock.

Polycyclic aromatic hydrocarbons
Molecules of hydrogen and carbon containing two or more rings of atoms.

A comet's tale

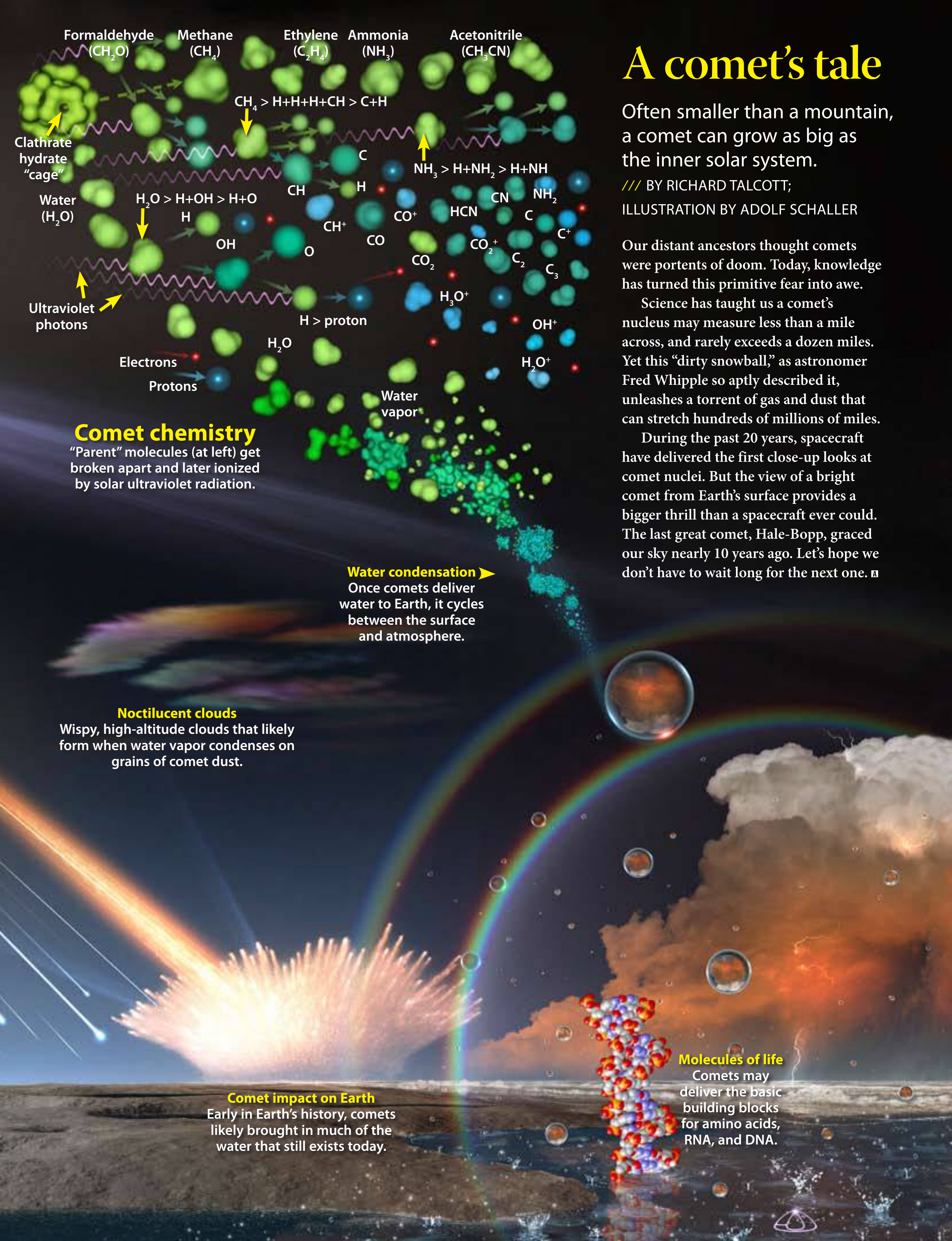
Often smaller than a mountain, a comet can grow as big as the inner solar system.

/// BY RICHARD TALCOTT;
ILLUSTRATION BY ADOLF SCHALLER

Our distant ancestors thought comets were portents of doom. Today, knowledge has turned this primitive fear into awe.

Science has taught us a comet's nucleus may measure less than a mile across, and rarely exceeds a dozen miles. Yet this "dirty snowball," as astronomer Fred Whipple so aptly described it, unleashes a torrent of gas and dust that can stretch hundreds of millions of miles.

During the past 20 years, spacecraft have delivered the first close-up looks at comet nuclei. But the view of a bright comet from Earth's surface provides a bigger thrill than a spacecraft ever could. The last great comet, Hale-Bopp, graced our sky nearly 10 years ago. Let's hope we don't have to wait long for the next one. A


Formaldehyde (CH_2O)
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Ethylene (C_2H_4)
Ammonia (NH_3)
Acetonitrile (CH_3CN)
Clathrate hydrate "cage"
CH_4 > H+H+H+CH > C+H
C
NH_3 > H+NH_2 > H+NH
Water (H_2O)
H_2O > H+OH > H+O
H
OH
O
CH
H
CH^+
CO
CO^+
HCN
CN
NH_2
C
C^+
CO_2
CO_2^+
C_2
C_3
H_3O^+
Ultraviolet photons
H > proton
OH^+
H_2O
Electrons
H_2O^+
Protons
Water vapor

Comet chemistry
"Parent" molecules (at left) get broken apart and later ionized by solar ultraviolet radiation.

Water condensation
Once comets deliver water to Earth, it cycles between the surface and atmosphere.

Noctilucent clouds
Wispy, high-altitude clouds that likely form when water vapor condenses on grains of comet dust.

Molecules of life
Comets may deliver the basic building blocks for amino acids, RNA, and DNA.

Comet impact on Earth
Early in Earth's history, comets likely brought in much of the water that still exists today.

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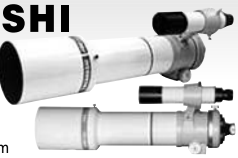

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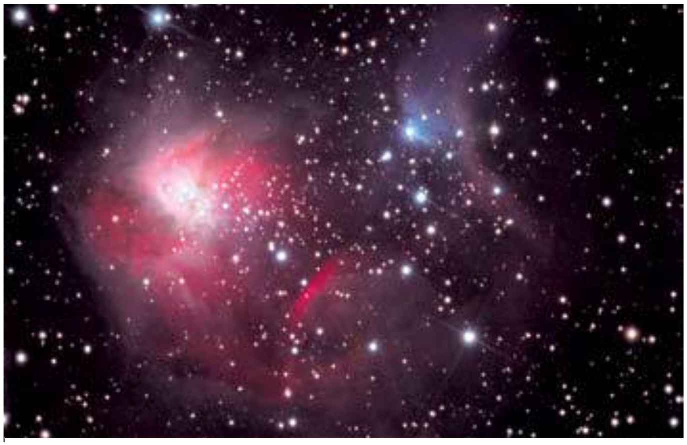
DEEP-SKY OBSERVING

Glowing gas clouds scattered along the Milky Way offer challenges for backyard observers. /// BY STEVE COE

Explore winter's overlooked nebulae

On a clear night, far from city lights, the stars this time of year seem to shine especially crisp and bright against the blackness of what appears to be empty space. It's not really empty, of course. Some of the sky's most interesting places are choked with glowing gas and dust.



AL AND ANDY FERAYORNI/ADAM BLOCK/NOAO/AURA/NSF

AVERTED VISION is your best ally when viewing the faint outer nebulosity of NGC 1931. Most of the nebula's glow comes from light reflected off of dust, so filters don't improve the contrast.

These regions look hazy in a telescope, so early astronomers christened them "nebulae." "Nebula" is the Latin word for cloud.

This article discusses two classes of nebulae: emission and reflection. An emission nebula glows because ultraviolet radiation from hot stars either near it or embedded within it energize the cloud's gas atoms and molecules into emitting light at the gas' characteristic colors. Scientists call this process fluorescence.

A reflection nebula glows because the cloud's dust grains reflect light from nearby stars. Perhaps the most familiar example is the dusty veil around the Pleiades star cluster (M45) in Taurus the Bull.

The sky is full of both types of nebulae. Some, like the Orion Nebula (M42) are bright and easy to study, but, after a while, most observers want more of a challenge. Modern nebula filters not only enhance views of old favorites — they put many new nebulae within your reach. We'll tour a few well-known targets, but mainly we'll focus on nebulae in the late-autumn/early-winter northern sky you might have passed by.

Surveying Auriga

Our first object is **IC 410**, a nebula associated with the open star cluster NGC 1893 in Auriga. The stars are part of a large stellar association named Auriga OB2, a rich collection of hot, young, and massive O- and B-type stars. Radiation from these stars easily strips electrons from neutral gas atoms, ionizing them and causing them to glow. Intense radiation and strong stellar winds compress some of the surrounding gas, triggering the formation of more stars within the cloud.

A 6-inch telescope at 40x will resolve 18 bright cluster stars. This stellar group is easy to distinguish from the Milky Way's background glow. Using averted vision — a technique in which you look slightly away from a target to use a part of the eye more sensitive to light — reveals a ghostly nebular glow within the cluster. The brightest part of the nebula actually lies outside the cluster and is still faint at this aperture, but an ultra-high-contrast (UHC) filter brings out its glow.

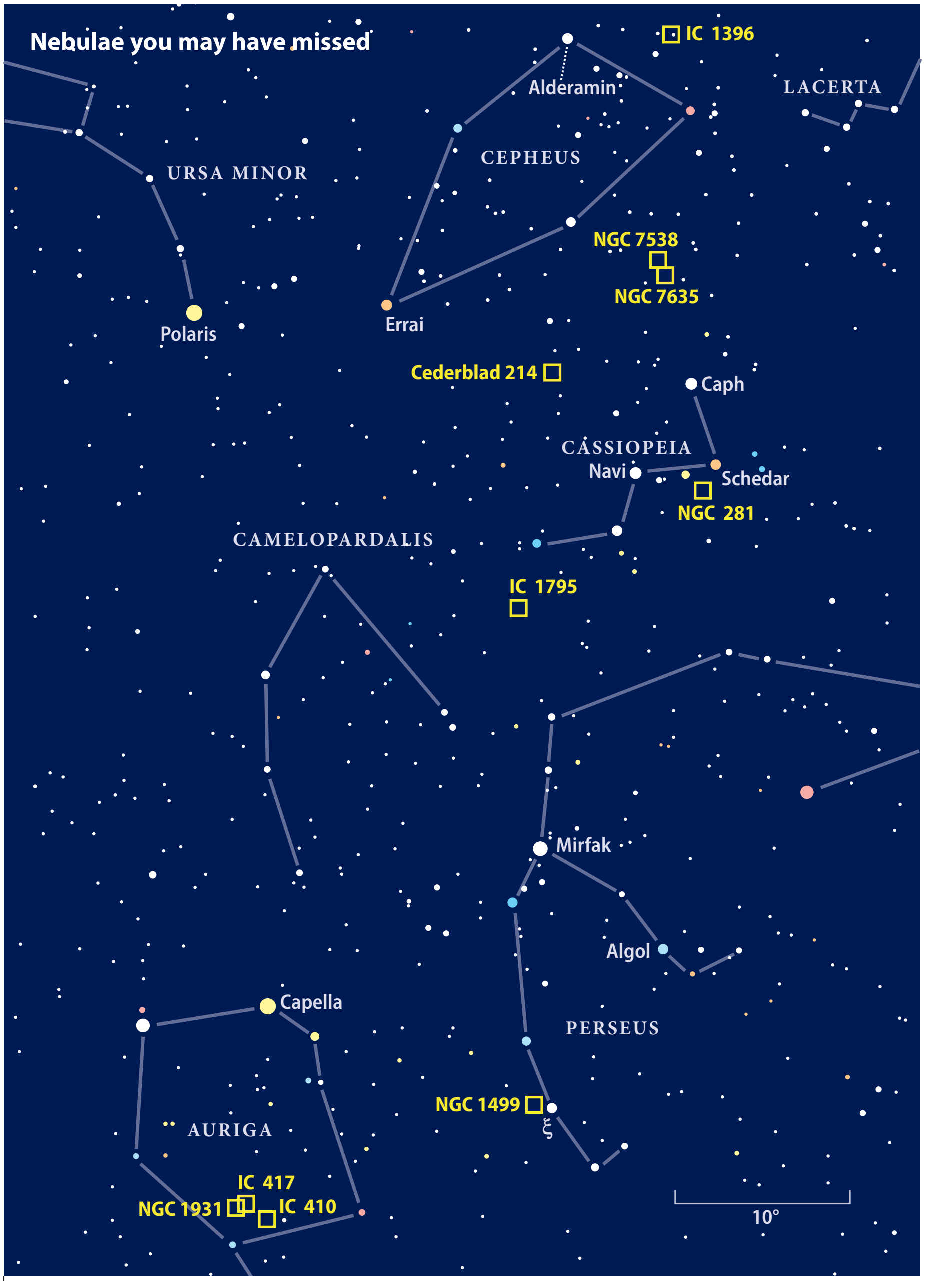
Moving up to my 13-inch f/5.6 Newtonian reflector at an excellent site far from the lights of Phoenix, I saw the cluster as bright, large, and elongated. I counted 61 stars at 85x with a 22mm eyepiece. Without a filter, the nebula is a faint, irregular figure around the cluster. Adding a UHC filter makes the nebula more obvious. IC 410 is brightest on its northwestern edge and faintest at its southern extent, seemingly surrounding the cluster in a horseshoe shape. Combining averted vision with a UHC filter fills in the field with the barely visible gas.

NGC 1931 is an open cluster harboring both emission and reflection nebulae. Observing with the 13-inch at 100x on a night I rated 7 out of 10 in transparency, this object looked reasonably bright and large, round, and brighter in the middle. Going to a higher power helped. Moving up to an 8.8mm eyepiece, which gave me 210x, I counted five stars shining within the glow.

This easily seen nebula is elongated 1.5' by 1' and oriented in position angle 45°

Steve Coe *has observed Arizona's skies for more than 25 years. Springer-Verlag will publish his next book,* Observing Nebulae, *in 2006.*

VIEWING NGC 1499 may conjure dreams of California on a winter's night. The California Nebula is about 100 light-years long and lies 1,500 light-years away. GEORGE GREANEY



ASTRONOMY: ROEN KELLY

EXPLORING early winter's nebulae takes you on a tour through the northern Milky Way's rich star fields, from Auriga and Perseus to Cassiopeia and Cepheus.

(northeast to southwest). Averted vision reveals some faint outer nebulosity, but neither a UHC nor a doubly ionized oxygen (OIII) filter improves the contrast. This means most of the nebula's glow comes from dust-reflected starlight.

With a 6-inch scope, the nebula resembles a comet, and, at higher powers, I can resolve the stars of NGC 1931. If the night will allow, use magnifications of 100x or better and try to split ADS 4112, a multiple star near the cluster's center. The three component stars shine at magnitudes 9, 10, and 11. Astronomers designate the brightest component A. The second-brightest star, B, lies 7" west-southwest of A, and the system's faintest member, C, shines 10" to A's northwest. There's a fainter component I could not see, even in the 13-inch at 300x.

The Queen's realm

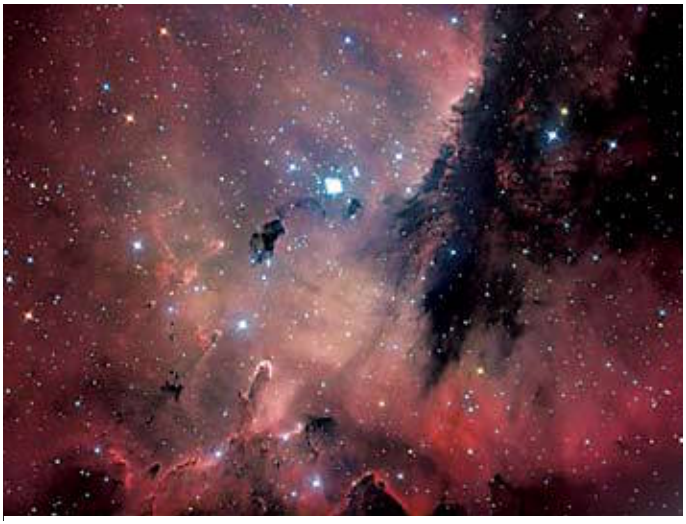
Resemblance to a video-game character gave **NGC 281** in Cassiopeia its whimsical nickname: the "Pac-Man Nebula." Easy to find and bright enough to show structure in every telescope I've owned, it's one of my winter favorites.

From the little town of Heber, Arizona, I could easily pick out the Pac-Man in my 6-inch f/6 Maksutov-Newtonian telescope. The nebula appears faint with no filter installed, but I could readily split its bright central star — Burnham 1 — using a 22mm eyepiece (42x). Adding a UHC filter makes quite a difference — the improved contrast makes the nebula unmistakable. An OIII filter also works well.

On excellent nights, my Celestron Nexstar 11-inch scope allows me to see lots of detail in NGC 281. Overall, at 125x with a UHC filter, the Pac-Man appeared bright and irregularly round, and filled the entire

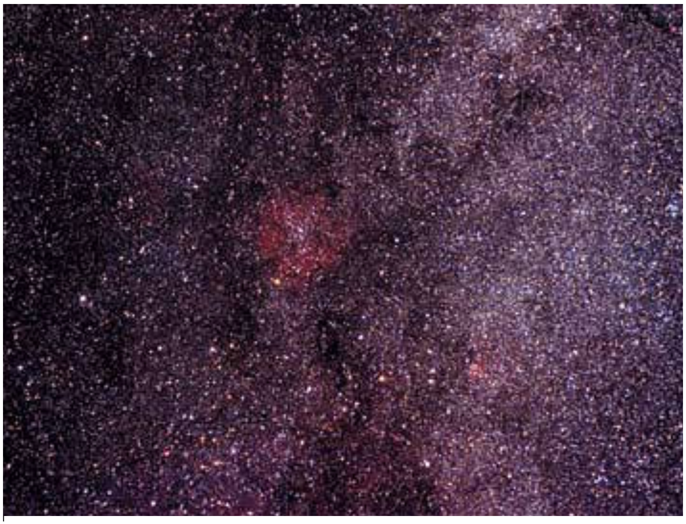
/// OBSERVING WINTER NEBULAE

Object	Constellation	R. A.	Dec.	Mag.	Size	Notes
Cederblad 214	Cepheus	0h04.7m	+67° 10m	—	50' by 40'	—
NGC 281	Cassiopeia	0h53.0m	+56° 37m	7.4	4'	—
IC 1795	Cassiopeia	2h25.8m	+61° 59m	—	12' by 12'	Brightest part of IC 1805; includes cluster Mel 15
NGC 1499	Perseus	4h03.2m	+36° 22m	5	160' by 40'	California Nebula, 0.6° from Xi Persei
IC 410	Auriga	5h22.7m	+33° 25m	7.5	11'	Includes open cluster NGC 1893
IC 417	Auriga	5h28.1m	+34° 25m	—	13' by 10'	—
NGC 1931	Auriga	5h31.4m	+34° 15m	10.1	3' by 3'	Contains multiple star ADS 4112
IC 1396	Cepheus	21h39.1m	+57° 30m	3.5	89'	Open cluster Trumpler 37 nearby
NGC 7538	Cepheus	23h14.1m	+61° 29m	—	8' by 7'	—
NGC 7635	Cassiopeia	23h20.2m	+61° 11m	11.0p	15' by 8'	Bubble Nebula



WOLFGANG PROMPER

NGC 281 is a star-formation workshop about 10,000 light-years away. Ragged, dusty globules may swaddle newborn stars, but one dark lane (right) creates the Pac-Man Nebula's gaping mouth.



JOHN CHUMACK

THE IC 1396 COMPLEX makes up for its faintness with size, sprawling some 2° across. Near open cluster Trumpler 37, bright nebulae silhouette dark, dusty ribbons.

field of view, which also contained a peppering of 28 stars. Several dark lanes run through the nebulosity — one creates the Pac-Man's "mouth." Without the UHC filter, the bright, central part of the nebula looks about the same, but the faint outer portions vanish. An OIII filter actually provides a better view of the nebula because it screens out many of the faint stars in the field of view. I like the UHC-filtered view best, but that's just one observer's opinion.

The King's territory

Emission nebula **Cederblad 214** in Cepheus the King is associated with an open star cluster called Berkeley 59. The cluster is a moderately tight group of 30 stars in the nebula's northern part. With a 13-inch scope at 100x, the nebula looks like little more than a widespread brightening of the background — even with a UHC filter. Without the filter, you won't see it at all, even on a good night.

While attending a Saguaro Astronomy Club star party, I heard someone say the object looks better with a Hydrogen-beta (Hβ) filter. In fact, the main glow of the nebula showed better contrast through that filter, and I noticed a dark intrusion into the cloud's north side, near the cluster, that I couldn't make out through the UHC filter.

A Hβ filter is usually the last type observers purchase, simply because few nebulae respond to it. So, it's good to have observing friends who are willing to share equipment you don't own.

IC 1396 is a cloud of dust and gas that lies some 2,500 light-years away and harbors the open cluster Trumpler 37. Several dark nebulae E. E. Barnard discovered a century ago also thread through the region, notably the Elephant Trunk Nebula. This is a busy part of the sky.

Because the brightest part of this nebula is more than 2° across, you'll need a telescope/eyepiece combination that gives at least that wide a field of view to see it all at once. With no filter, and using a 35mm eyepiece in my 6-inch scope, the faint nebula is barely visible. Threading in a UHC filter makes a tremendous difference. With it, an obvious glow surrounds the central cluster.

Another trick also helps bring out the nebulosity: Drape a dark cloth (sometimes called a "monk's hood") over your head to block external light from reaching your eyes. With the hood in place, the nebulosity is much easier to see. Once you've improved the view the best you can, take some time at the eyepiece. Look for several dark lanes that intrude into the edges of this fascinating object.

California in Perseus

Astronomers believe the star Xi (ξ) Persei, which lies about 1,500 light-years away, sets the California Nebula (**NGC 1499**) aglow. Shaped like its namesake, the nebula is about 1.5° long — 3 times the Full Moon's width — and you'll need a wide field of view to see it properly.

In fact, I was first able to pick it out using 10x50 binoculars one dark night. Once I was dark-adapted, it was easy. The 11x80 finder scope on my 13-inch Newtonian also gave an excellent view. When I installed a UHC filter into the finder's eyepiece, there it was — "California" in space, floating among the stars.

NGC 1499 stretches across the entire field of view in my 6-inch scope using a 35mm eyepiece. At the limit of vision, I could see dark bands running lengthwise along this glowing gas cloud.

The California Nebula benefits greatly from the use of an Hβ filter. Just holding the filter up to the sky, I could easily see the nebula's shape near Xi Persei. Moving the filter into and then out of my field of vision proved it's what made the difference.

Now's the time

Two types of glowing gas clouds aren't represented here: planetary nebulae and supernova remnants, both of which are associated with the end of a star's life and we will save them for another time.

Winter skies may be cold, yet they blaze with bright young stars. They are the legacy of the molecular clouds that gave them birth, now long dissipated into space. Our Sun and its planets formed in one of these clouds — possibly in an open cluster like those discussed above.

On the next clear night, take a trip off the beaten path and try tracking down these awe-inspiring but often overlooked targets. Imagine how spectacular these nebulae would look from nearer stars — and what now may be forming within them.

ONLINE EXTRA Come to www.astronomy.com/toc for a gallery of must-see nebulae.

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Ask Astro

Interstellar comets, aligning finders, and taking space's temperature

INTERSTELLAR COMETS

Have we ever seen comets from beyond the solar system? — NOZOMU KANEDA

The notion that clouds of comets surround stars — including the Sun, of course — predates by some two decades Jan Oort's concept of what we nowadays call the Oort comet cloud.

Astronomer Ernst Öpik believed many meteors were moving through the solar system on unbound, or hyperbolic, orbits with respect to the Sun. A particle following such a path would pass only once through the solar system, never to return. Öpik championed the idea that such clouds around nearby stars created a large population of interstellar comets and meteors.

An observing program initiated by Fred Whipple in the late 1930s quickly showed no convincing case of a hyperbolic meteor. And Oort's calculations based on the orbits of comets before they entered the inner solar system showed little evidence for any hyperbolic comets.

Indeed, what few slightly hyperbolic comets there seemed to be could be eliminated by amending the calculations to take into account the comet's reaction to solar heating. According to Whipple's "dirty snowball" model, ice vaporizing off a comet nucleus near the Sun creates a small thrust, forcing a slight change in the comet's speed.

What we have learned about comets and meteors does not completely exclude the possibility of an occasional visitor from some other star's cometary cloud arriving in Earth's vicinity. An interstellar comet would be moving slightly faster than those native to the solar system, but astronomers estimate such an event occurs only a couple of times a millennium. — **BRIAN G. MARSDEN,** HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS, CAMBRIDGE, MASSACHUSETTS

JOHN A. VOLK

A COMET as active as Hale-Bopp can scatter more sunlight than Earth itself. Space telescopes designed to image earthlike planets around other stars will be able to see similarly energetic comets as well. Astronomers think comets that have escaped from other stars might pass through our solar system a couple of times each millennium.

ALIGNING FINDERS

I'm having trouble centering the objects I want to observe in my telescope. Can you help me? — TERRA REMPE, SMITH CENTER, KANSAS

Just about all observers align their finder scopes every time they go out to observe. It makes observing easier, more efficient, and more enjoyable.

Here's how to do it: In daylight, set up your telescope. You'll want to use the eyepiece that gives you the lowest magnification, so it will be the one with the largest number on it. For example, if you have two eyepieces labeled 10mm and 25mm, choose the 25mm eyepiece.

Point your scope toward a distant, not-too-large terrestrial object — like the top of a telephone pole or the edge of a building. Center it in your eyepiece and focus.

Without moving your telescope, look through the finder. Most finders have crosshairs that meet in the field of view's center. If you're having trouble locating objects when moving from the finder to the telescope, the object you just targeted with the finder won't appear in the scope's field of view either. You'll need to reposition the finder so its crosshairs appear centered on the spot where the scope is now pointing.

Either three or six adjusting screws hold a finder in place. Look through the finder and slowly turn one of the screws. Move the finder onto the target as best you can, then repeat the process for the other screws until the finder's crosshairs are pointing where you want them. Now your finder is aligned.

When you go out at night, use the finder to locate the object you want to view. The finder's low magnification and wide field of view make it easy to find what you're looking for. And now, when the object appears centered in your finder scope, it should also be centered in your telescope.

If your scope gets bumped or frequently moved, you might have to align your finder scope again. But each time you do, it will take you less time. — **MICHAEL E. BAKICH,** ASSOCIATE EDITOR

TAKING SPACE'S TEMPERATURE

If space is empty, and if temperature measures how fast particles move, then how can space have a temperature? — **PAUL LAFRENIERE,** VERNER, ONTARIO

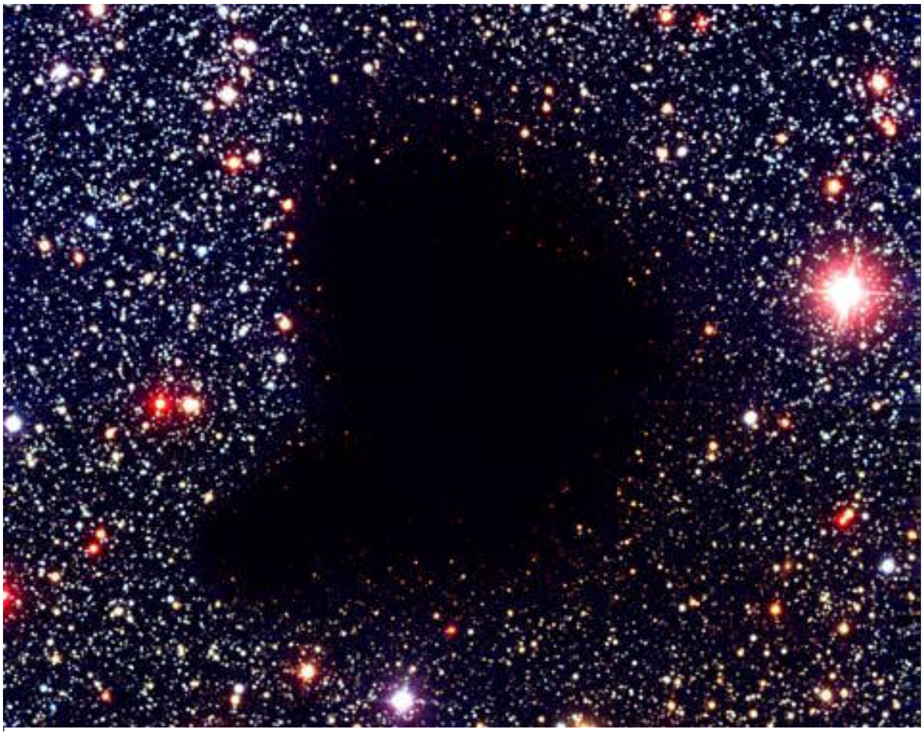
Space is not empty. It contains very tenuous gases, plasmas, and various types of radiation, like light, infrared, ultraviolet, X rays, etc. As you note, we're measuring the average speed of randomly moving particles when we measure temperature.

The solar wind, which consists of electrically charged gases (ions and electrons) flowing away from the Sun at 850,000 mph (1.3 million kilometers per hour) on average, permeates interplanetary space. Near Earth, each cubic centimeter of space — a volume equivalent to that of a sugar cube — contains between 100 and 10,000 of these particles.

In interstellar space, between the stars of our Milky Way Galaxy, we'd find about one particle in every cubic centimeter. In intergalactic space, between the galaxies of our universe, we would need to expand our sampling volume by a million times — to a cubic meter, or 35 cubic feet — in order to catch anywhere between 1 and 100 ions, electrons, and neutral atoms.

Although the densities of these gases are at least 1,000 million million (10^{15}) times thinner than air, they are not zero. The temperatures of these gases range from only a few degrees above absolute zero (the temperature of cold interstellar clouds) to over a hundred million degrees (the temperature of some intergalactic plasma).

But, even if a certain volume of space were completely empty of particles, it would still contain several forms of radiation, such as diffuse starlight, and the residual microwave radiation from the Big Bang.



ESO

BARNARD 68 lies 410 light-years away and is one of the nearest dark clouds. Placed in our solar system, its outer fringes would extend into the Oort comet cloud, more than 5,000 times Earth's distance from the Sun. This dense cloud of interstellar dust — about twice our Sun's mass — holds a rich store of different molecules, and, for the moment, appears to be stable against collapse. The temperature inside the cloud falls to –431° F (–257° C).

Imagine a thermometer floating in space. As rarefied particles collide with this thermometer, the energy they transfer to it will increase its temperature bit by bit. The thermometer also will lose some of this energy by emitting infrared radiation (heat). The thermometer's temperature is a balance between energy gained by particle collisions and radiation versus energy lost by giving off heat.

For a large, solid object embedded in a very tenuous, but hot, gas, this balance point is usually much colder than the gas temperature as indicated by its particle motions. Placed in intergalactic space, such an object would typically stabilize at a temperature less than 10 kelvins (–436° F [–260° C]). This is why we think of space as being frigid.

If we placed our thermometer somewhere that was completely devoid of all matter — that is, a true vacuum — its temperature would come to equilibrium with energy absorbed from radio waves, light, and the other radiation permeating space, such as the cosmic microwave background.

In deep intergalactic space, our thermometer would register a temperature of just 2.7 K (–454.8° F [–270.5° C]).

In deep interstellar space, the light of distant stars would raise its temperature between 4 and 10 kelvins more, depending on the details of the environment.

Placed near Earth and exposed to sunlight, the thermometer would reach a temperature close to Earth's average surface temperature: 288 K (59° F [15° C]). — **JOHN BALLY,** UNIVERSITY OF COLORADO AT BOULDER

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

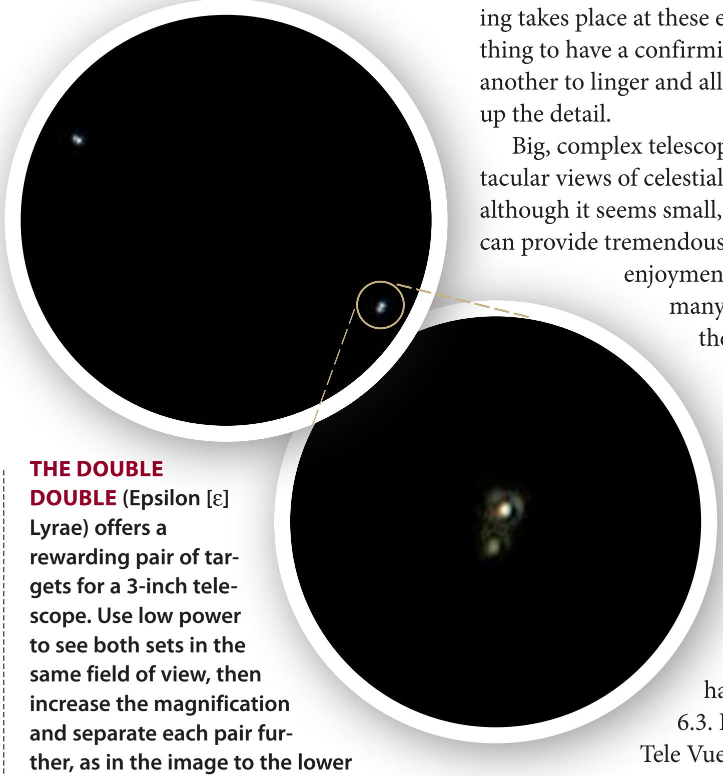
OBSERVING

Under a dark sky, even a small telescope reveals the wonders of the cosmos.

/// BY RAYMOND SHUBINSKI

Around the universe with a 3-inch scope

"You see, but you do not observe; there is a distinction." — Sherlock Holmes to Dr. Watson in *A Scandal in Bohemia*. The great fictional detective might have been talking to any of us who enjoys amateur astronomy. A star party, for example, is a wonderful place to see what's new with telescopes. Giant reflectors on Dobsonian mounts tower above the dark horizon like cannons ready for battle. Schmidt-Cassegrain telescopes of every size glow with indicator lights, and sleek refractors on advanced equatorial mounts stand at the ready.



THE DOUBLE DOUBLE (Epsilon [ε] Lyrae) offers a rewarding pair of targets for a 3-inch telescope. Use low power to see both sets in the same field of view, then increase the magnification and separate each pair further, as in the image to the lower right.

DAMIAN PEACH

A go-to drive, with its miniature computer that has thousands of entries in its log, is more than enough to keep an observer busy all night. The pace can become frenzied with gears whirring and scopes turning, finding object after object to the delight of all. But how much observing takes place at these events? It's one thing to have a confirming look, and another to linger and allow your eye to soak up the detail.

Big, complex telescopes provide spectacular views of celestial objects. And although it seems small, a 3-inch telescope can provide tremendous freedom and the enjoyment of an evening — many evenings — under the stars.

To prove this, I brought together a stack of old sky guides and two refractors: a classic 3-inch Unitron, which operates at f/15, and a new 3-inch Tele Vue-76, which has a focal ratio of 6.3. I used the following Tele Vue eyepieces: 24mm and 35mm Panoptic and 5mm, 7mm, 11mm, 13mm, and 22mm Nagler. The long focal length of the Unitron (1,200mm) provided exactly 2.5x more magnification than the Tele Vue (focal length 480mm) using the same eyepiece.

ALBIREO (Beta [β] Cygni) is one of the finest double stars in the sky. Most observers see its components colored golden and sapphire blue, but, because each person's visual perception of color differs, you'll have to assign your own colors to them.

DAMIAN PEACH

Double vision

I started with a list of well-known double stars to see how my observations compared with the sky guides' authors. Double stars provide a great testing ground for any telescope and help establish its performance.

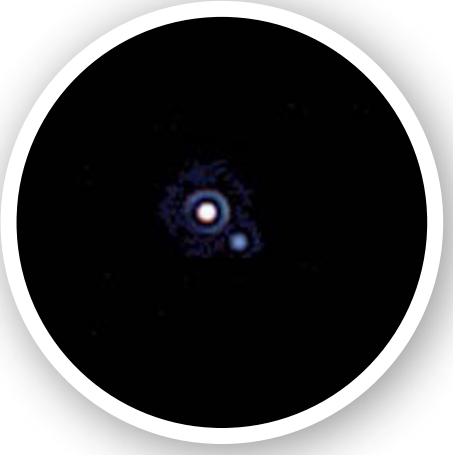
In the bend of the Big Dipper's handle, I located many observers' favorite double

---

Raymond Shubinski *is director of Science City/Attractions in Kansas City, Missouri, and a big fan of small-scope observing.*

ERIC THOMAS

THE AUTHOR READIES HIMSELF and the telescopes he used for this story: a 3-inch f/6.3 Tele Vue-76 apochromatic refractor (left) and a 3-inch f/15 Unitron achromatic refractor.



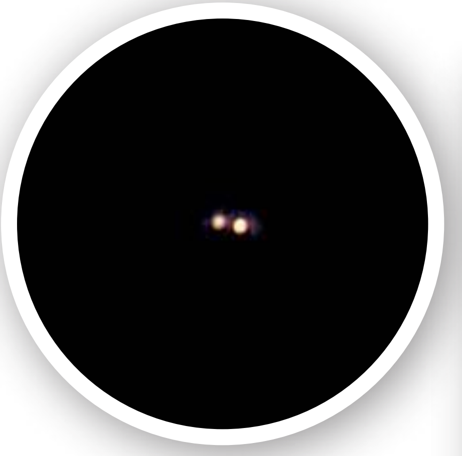
PULCHERRIMA, a name that means "most beautiful," aptly describes Epsilon (ε) Boötis. Do you see a yellow and green pair, a white and blue pair, or some other colorful combination? Whichever you see will require high magnification. The stars shine at magnitudes 2.5 and 4.9, but they're only 2.8" apart. DAMIAN PEACH

star: Mizar (Zeta [ζ] Ursae Majoris) and Alcor (80 Ursae Majoris). Long used as a test for acute eyesight, only low power is needed to see this splendid pair. Mizar further splits into an optical double: two stars not physically close but in the same direction. Even with the 24mm eyepiece in the Tele Vue (20x), both components of Mizar were easy to see.

A bit more difficult is Polaris (Alpha [α] Ursae Minoris). Besides its fame as the pole star, Polaris is an attractive double that will test a 3-inch scope. If your scope is on an equatorial mount, you may need to offset it slightly to center Polaris. Sky conditions and patience are everything. This magnitude 2 star has a 9th-magnitude companion only 18" away. With a 7mm eyepiece in the Unitron (171x) under good conditions, I was able to see the two stars.

Turning the Tele Vue-76 on Polaris gave an incredible view. With the 5mm eyepiece (96x), Polaris shone like a gem. The wide field and high contrast revealed new wonders. In this field, it's easy to see both the nearby magnitude 6.5 star SAO 209 and, 1.5° away, Lambda (λ) Ursae Minoris. Lambda's red color is easy to see. Look at Polaris again and find a small circlet of faint stars nearby. This is the "engagement" ring — Polaris is the diamond.

Turning the scopes toward Boötes, I found Epsilon (ε) Boötis. I then referred to Garrett P. Serviss' classic book *Pleasures of the Telescope* (1901). Serviss called this double star "the flower of the sky," and Friedrich G. W. Struve dubbed it Pulcherrima ("most beautiful"). This is a tough double to split with a 3-inch telescope, but it can be done with good conditions that allow high magnification. The primary is magnitude 2.5 while the magnitude 4.9 companion is only 2.8" away.



GAMMA (γ) LEONIS lies in the sickle of Leo, just above Regulus (Alpha [α] Leonis). The brighter star shines at magnitude 2.2 and has a yellowish hue. Its companion glows a bit fainter, at magnitude 3.5. What color does it appear to you? Observers have reported colors ranging from pale red to green. DAMIAN PEACH

This pair provokes any number of over-the-top descriptions. Serviss calls them "bright orange-yellow, set against brilliant green." Other observers see them as distinctly yellow and bluish — some even report a green tinge. Both the Unitron and the Tele Vue needed high magnification to split the stars. At times, the components seemed to merge, but, in moments of good seeing, the 5th-magnitude companion popped into view. When this happens, the color contrast is startling.

/// WRITERS ON THE SKY

For more great objects to observe with your small telescope, check out these recent *Astronomy* stories.

"Trekking the autumn sky"
by Ian Ridpath — September 2004

"The Caldwell Catalog"
by Michael E. Bakich — October 2004

"Wander the winter sky"
by Ian Ridpath — December 2004

"See a star die"
by Doug Snyder — February 2005

"Explore the spring sky"
by Ian Ridpath — March 2005

"Summer splendors"
by Ian Ridpath — July 2005

"The ABCs of observing"
by Michael E. Bakich — *Explore the Universe 2005*

As the night rolls on and Cassiopeia moves higher in the sky, Eta (η) Cassiopeiae presents another good target. This is an easy double through a 3-inch — the stars

MIZAR AND ALCOR (Zeta [ζ] and 80 Ursae Majoris) mark the bend of the Big Dipper's handle. Most observers can split this pair with their unaided eyes. But use a telescope, and, even with low power, Mizar (lower left) splits again. DAMIAN PEACH

POLARIS (Alpha [α] Ursae Minoris) is a more difficult double to split with a 3-inch scope than Mizar. The separation of 18" is fairly wide, and the primary star shines at magnitude 2. A real challenge is seeing the companion, which glows weakly at 9th magnitude. DAMIAN PEACH

SID LEACH AND WIL MILAN/ADAM BLOCK/NOAO/AURA/NSF

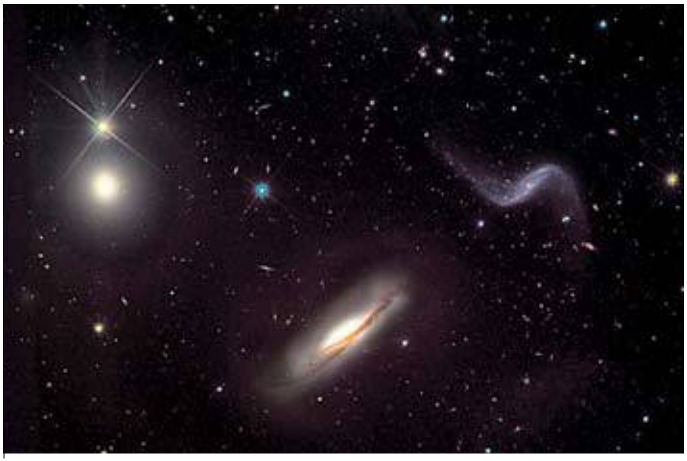
INTERACTING GALAXIES NGC 3226 (left) and NGC 3227 lie 1° east of Gamma (γ) Leonis. To view them, pick a site away from city lights when the Moon's not up. NGC 3227 shines at magnitude 10.3, and, although NGC 3226 is fainter overall, its small size gives it a higher surface brightness than its companion.

are magnitudes 3.4 and 7.5 separated by 12" — and a 7mm eyepiece in the Tele Vue easily split them. Again, what colors you'll see depends on your eyes. Serviss saw white and purple, but, to me, through the Tele Vue, they appeared yellow and pale red. If you're observing with others, have everyone take a look and compare notes. Most likely each observers' impression will be different.

Turning to the constellation Canes Venatici, I located Cor Caroli (Alpha Canum Venaticorum). This is a wide double and requires little magnification to split. Old observing books list this pair as yellow and blue. Through both 3-inch scopes, the difference in color was hard to detect, but this is a beautiful pair with magnitudes of 2.9 and 5.5 and a separation of 19.4". For a brief period around 1675, Cor Caroli was the entire constellation's name. The physician of King Charles I of England invented it to honor his liege.

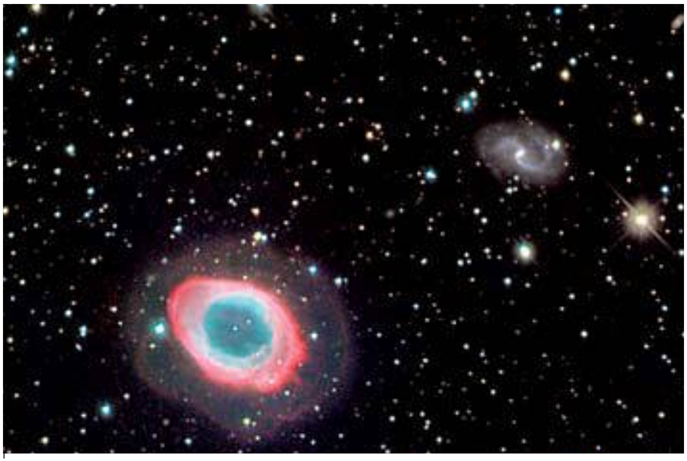
Another beauty — and a favorite for small scopes — is Algeiba (Gamma [γ] Leonis). This pair is fairly bright at magnitudes 2.2 and 3.5, and with a separation of 4.4", it's an easy split in a 3-inch scope. Once again the perception of color comes into play. Many observers report the two stars as yellow and red, but American astronomer William Tyler Olcott (1873–1936) saw them as yellow and green. Through the Unitron, using an 11mm eyepiece (109x), I judged both stars about the same shade of pale yellow. Through the better-color-corrected Tele Vue with the 5mm eyepiece (96x), however, the companion seemed to have a hint of red.

Some sights never leave an observer. The first time you see Epsilon Lyrae is one of those. Epsilon is the famous Double Double, which has always been a good test for both a telescope and atmospheric conditions. At low power, it becomes apparent that Epsilon is double. Both "stars" shine at



ADAM BLOCK/NOAO/AURA/NSF

HICKSON 44, **also known as the NGC 3190 group, lies at the visual limit of a 3-inch telescope. Patience under a dark sky should reward you with a glimpse of this compact galaxy cluster, which lies approximately 60 million light-years from Earth.**



ADAM BLOCK/NOAO/AURA/NSF

THE RING NEBULA **(M57) in Lyra is one of the best-known planetary nebulae. M57 lies midway between two relatively bright stars, Beta (β) and Gamma (γ) Lyrae. It shines at magnitude 9.7 and measures 71" across.**

5th magnitude with a separation of 208". Crank up the magnification, and the two stars split once again: The first pair has magnitudes 5.0 and 6.1 and a separation of 2.6"; magnitude 5.2 and 5.5 stars separated by 2.3" comprise the second pair. The Double Double appears like two pairs of automobile headlights at right angles. All four stars have a bluish tint.

Another quadruple treat lies in Lyra. The combination of Struve 2470 (magnitudes 6.6 and 8.6, separation 13.4") and Struve 2474 (6.5 and 8.6, separation 16.4") compares well with Epsilon Lyrae. The two pairs are parallel to one another and fainter, so use higher magnification to split them.

To cap off an evening of double-star hunting, don't miss Albireo (Beta [β] Cygni), which marks the head of Cygnus the Swan. At summer and fall public star parties, Albireo is one of the first objects shown. Serviss says these stars' colors look as if they were produced with the purest of paint pigments. Most observers describe them as yellow and blue. Eyes differ, though, so your colors may vary. To me, they appeared golden (magnitude 3.1) and a deep blue (magnitude 5.1) through both 3-inch scopes. Their separation is a relatively wide 34.4".

Other deep-sky objects

If you observe with a 3-inch telescope, thousands of star clusters, nebulae, and galaxies also lie within your reach. So when you're observing doubles in Leo, sweep less than 1° east of Gamma Leonis to find a double galaxy: NGC 3226 and NGC 3227. You'll need a dark sky to see this pair.

/// REFLECTIONS ON THE SMALL-REFRACTOR ERA

There is no denying that large-aperture instruments provide spectacular views. Access to such large and sophisticated telescopes is a fairly recent privilege for amateur astronomers. Scanning through astronomy catalogs from the 1950s and 1960s provides a glimpse of what observers valued in a telescope then. The 6-inch reflector was popular, but the pages with 3-inch refractors on simple wooden mounts are the most thumbed.

Looking through 100-year-old popular astronomy books reveals the dominance of the refractor. In particular, refractors with 3-inch objective lenses were most popular. The most familiar 19th- and early 20th-century telescope-makers are Alvan Clark & Sons and John Brashear.

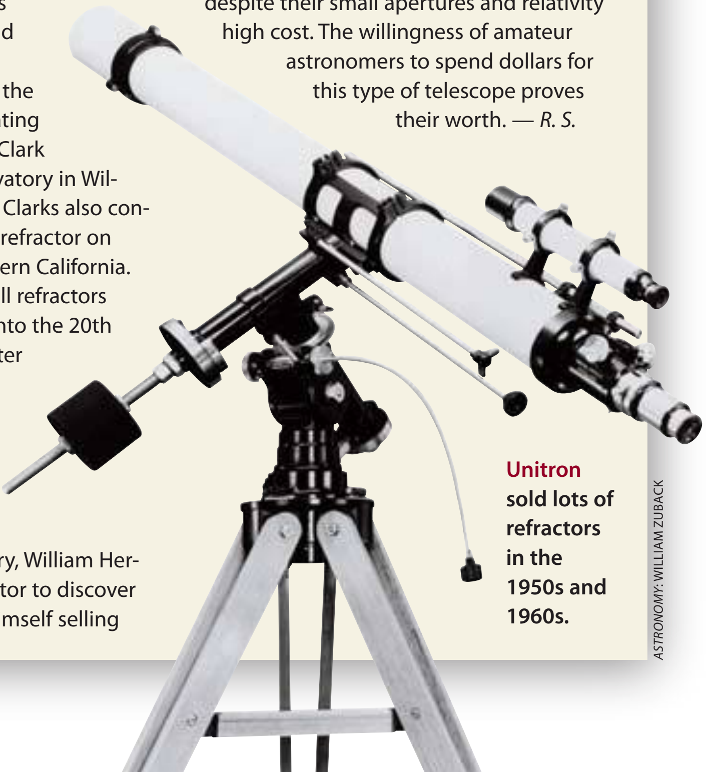
The 19th century was the age of refractors, culminating in 1895 with the 40-inch Clark refractor at Yerkes Observatory in Williams Bay, Wisconsin. The Clarks also constructed the 36-inch Lick refractor on Mount Hamilton in northern California.

The popularity of small refractors for amateurs continued into the 20th century. Seventy years after Yerkes saw first light, the refractor was still preferred and is once again becoming a favorite of 21st-century amateur astronomers.

In the late 18th century, William Herschel used a 6-inch reflector to discover Uranus. He soon found himself selling reflecting telescopes throughout Europe. So what happened? How did the refractor come to rule?

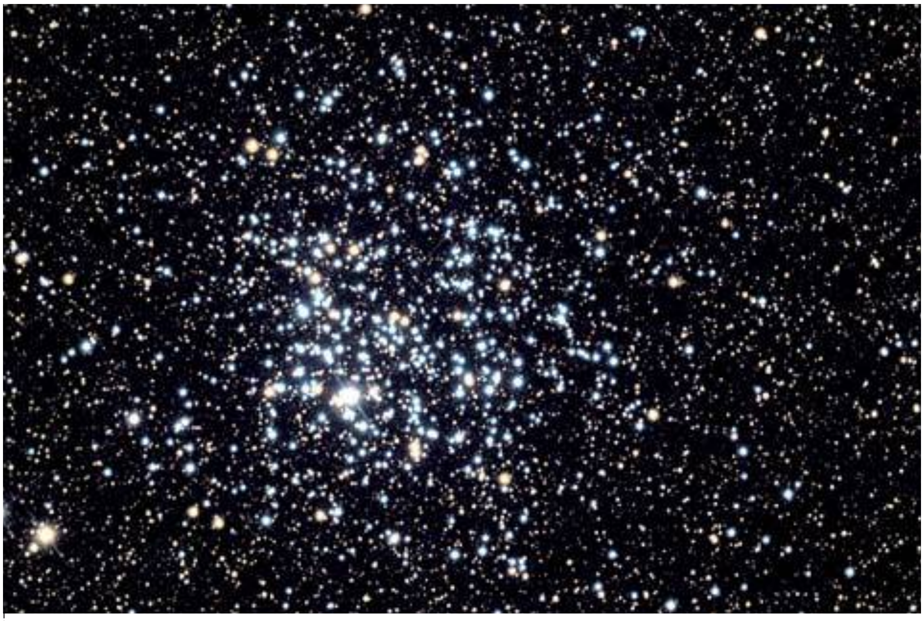
The mirrors in early reflecting telescopes were made of an alloy called speculum, which is an amalgam of copper and tin. It had great reflective qualities, but it tarnished quickly and required frequent polishing. So, most astronomers stuck with refracting telescopes. High cost and low maintenance were major factors, but long-focal-length refractors also provided outstanding views. As a result, refractors dominated astronomy for 150 years.

Many modern observers have discovered the joy of using high-quality refractors despite their small apertures and relativity high cost. The willingness of amateur astronomers to spend dollars for this type of telescope proves their worth. — *R. S.*



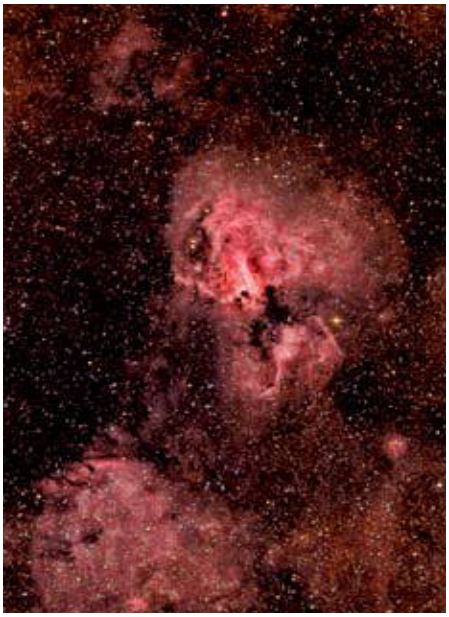
Unitron **sold lots of refractors in the 1950s and 1960s.**

ASTRONOMY: WILLIAM ZUBACK



ADAM BLOCK/NOAO/AURA/NSF

THE WILD DUCK CLUSTER (M11) was named by William Smyth in the mid-19th century. In his small scope, this object resembled a flight of wild ducks across the sky. See how many stars you can resolve by starting with low power and increasing the magnification until the atmosphere's unsteadiness stops you.



ADAM BLOCK/NOAO/AURA/NSF

THE SWAN NEBULA (M17) in Sagittarius looks like its namesake only when you view it with low magnification. For the best views of this and many other bright and planetary nebulae, use an OIII filter. Such a device screws into the bottom of your eyepiece.

/// 10 NEBULAE FOR SMALL SCOPES

Object	Right ascension	Declination	Magnitude	Constellation
The Orion Nebula (M42)	5h05m	–5°37'	4.0	Orion
The Rosette Nebula (NGC 2237)	6h02m	5°03'	4.8	Monoceros
The Ghost of Jupiter (NGC 3242)	10h25m	–18°38'	7.8	Hydra
The Owl Nebula (M97)	11h15m	55°01'	9.9	Ursa Major
The Cat's Eye Nebula (NGC 6543)	17h59m	66°38'	8.1	Draco
The Blinking Planetary (NGC 6826)	19h45m	50°31'	8.8	Cygnus
The Dumbbell Nebula (M27)	20h00m	22°43'	7.3	Vulpecula
The Helix Nebula (NGC 7293)	22h30m	–20°48'	7.3	Aquarius
The Blue Snowball (NGC 7662)	20h35m	28°18'	8.3	Andromeda
The North America Nebula (NGC 7000)	20h59m	44°20'	—	Cygnus

Scan about halfway from Gamma to Zeta Leonis, and you'll come upon a group of galaxies you may not have heard of, but one that's well worth observing: Hickson 44, also known as the NGC 3190 group, after its brightest galaxy (magnitude 11). The wide field and sharp contrast of a telescope like the Tele Vue proves its worth in providing a glimpse of these galaxies.

And, speaking of bright galaxies, don't miss a half-dozen more in Leo. One-third the distance from Regulus (Alpha Leonis) to Denebola (Beta Leonis) lie M95, M96, and M105. And halfway from this trio to Beta lie M65, M66, and NGC 3593.

Back in Lyra, one celestial object is high on the "don't miss" list: the Ring Nebula (M57), a classic example of a planetary nebula. M57 lies midway between Beta and Gamma Lyrae. Through the Unitron using a 13mm eyepiece, this object's nature can be glimpsed, barely. It appears as a tiny, slightly elliptical magnitude 9.7 ring 71" across, surrounded by stars. Under good seeing conditions, it appears hard-edged — a definite illusion.

During summer, the Milky Way stretches from the northeast to high overhead and down to the southwest. A line extended south from Albireo will pass through one of the odd constellations in this region: Scutum the Shield, invented in 1690 by German astronomer Johannes Hevelius. It's home to the beautiful open star cluster M11, which shines at magnitude 5.8. Because it's a large 13' across, M11 is best observed with medium-to-low power. I used a 24mm eyepiece in the Tele Vue (20x) for a wide view and an 11mm eyepiece in the Unitron (109x) for a closer look. In both cases, the entire cluster fit nicely in the field of view. M11 is rich in blue and white stars. It appears to have a fan or V shape. In his *Cycle of Celestial Objects* (1844), English astronomer William Smyth compared M11 to a "flight of wild ducks." Look carefully, and you'll see an 8th-magnitude star that appears to be leading the flock.

So many great objects inhabit this region of sky. Continue using low power and scan over to the star clouds of Sagittarius. You'll pass the Swan Nebula (M17), which measures 20' by 15'; the Trifid Nebula (M20), with a diameter of 20'; and the Lagoon Nebula (M8), measuring 45' by 30'. These three objects are showpieces through a 3-inch scope, especially if you use a nebula filter such as an OIII. This narrowband filter reduces both starlight and stray light, letting the specific wavelengths of light

JEFF AND PAUL NEUMANN/ADAM BLOCK/NOAO/AURA/NSF

THE LAGOON NEBULA (M8) in Sagittarius has few rivals for the title "most spectacular" nebula. Plan on spending lots of time observing the twists and whorls within this object. M8 is big, measuring 1.5 Full Moons long by 1 Full Moon wide.

GEORGE SEITZ/ADAM BLOCK/NOAO/AURA/NSF

GLOBULAR CLUSTER M4 IN SCORPIUS lies near Antares (Alpha [α] Scorpii). M4 is visible to the naked eye from a dark site, but use your telescope to bring out the best of this cluster. With a 3-inch scope, you'll count more than 50 stars.

from these nebulae pass through. The result? You get a better view.

When you can see M8 well, Scorpius is as high in the south as it will get. The scorpion is full of clusters and other fascinating objects for 3-inch scopes. Beta Scorpii is a beautiful double that split easily through both telescopes at low power.

The flaming red star Antares (Alpha Scorpii) also is a beautiful double. But this pair is difficult to split with a 3-inch telescope. Antares shines at magnitude 1.1, and its companion is magnitude 5.4. Because the separation is only 2.6", Antares overwhelms the companion.

I used high power in both telescopes to catch a glimpse of the companion. If you throw the star image slightly out of focus, you can see diffraction rings, which result from light's wave nature. You may see a thickening of one of these diffraction rings around Antares, indicating the presence of another star. Antares appears red, and, if you spot the companion, it may have a greenish tinge. There are no green stars, and this color is an illusion — a contrast effect caused by Antares' redness.

For another great sight, insert a low-power eyepiece, and look slightly northwest, keeping Antares in view. The jewel you'll encounter is globular cluster M4. Most observers can see it with their naked eyes under a dark sky. Shining at magnitude 5.6, M4 rewards every increase in magnification with a better view.

When you look through your telescope, linger over each object. To paraphrase Sherlock Holmes: Don't just go out and see the stars; take time to observe them. ■

LAWRENCE JOHNSON AND KATHY ORTEGA/ADAM BLOCK/NOAO/AURA/NSF

THE TRIFID NEBULA (M20) IN SAGITTARIUS is a combination of bright and dark nebulae. The dark areas are dust and cold gas that block the light from the bright emission nebulae behind them. This object demands high magnification, so use as much as atmospheric conditions allow. Try a nebula filter if any light pollution is present.

/// 10 STAR CLUSTERS FOR SMALL SCOPES

Object	Right ascension	Declination	Magnitude	Constellation
The Owl Cluster (NGC 457)	1h19m	58°20'	6.4	Cassiopeia
M37	5h52m	32°33'	5.6	Auriga
M41	6h47m	–20°44'	4.5	Canis Major
NGC 2362	7h19m	–24°57'	4.1	Canis Major
M3	13h42m	28°23'	5.9	Canes Venatici
The Hercules Cluster (M13)	16h42m	36°28'	5.7	Hercules
M22	18h36m	–23°54'	5.1	Sagittarius
The Coathanger (Collinder 399)	19h25m	20°11'	3.6	Vulpecula
M15	21h30m	12°10'	6.0	Pegasus
M2	21h33m	–0°49'	6.4	Aquarius

ASTRONOMICAL HISTORY

Tele Vue's introduction of the Nagler eyepiece 25 years ago started a revolution in high-quality optics. /// BY MICHAEL E. BAKICH

The eyepiece that changed observing

Amateur astronomy has marked a number of great moments: the first Schmidt-Cassegrain telescope, the first time a reflector was put on a Dobsonian mount, and the first go-to drive, to name a few. Count with these benchmarks the introduction of the Tele Vue 13mm Nagler eyepiece. That eyepiece was the first to offer both a large apparent field of view and sharp images.

To mark the 25th anniversary of the first Nagler eyepiece, I traveled to Chester, New York, where I toured the facility and spoke with the Nagler family.

Lifetime focus

Al Nagler, founder and CEO of Tele Vue Optics, was both an amateur astronomer and a successful optical designer before he formed his company in 1977. As a youth attending the Bronx High School of Science in the 1950s, he built his first telescope — an 8-inch f/6.5 reflector that, with its mount, weighed 350 pounds. And what a start this was. The project earned Nagler a prize (a micrometer) at graduation, $80 from *Mechanix Illustrated* (payment for an article detailing how he made it), a Stellafane award, and a job interview at Farrand Optical Company in the Bronx, New York.

Nagler had a productive optical design career at Farrand from 1957 to 1973. While there, he designed the optics for the visual simulator that was used to train astronauts to pilot the Gemini spacecraft and the Apollo lunar module.

Tele Vue
NAGLER
F=13.0mm

THE 13MM TELE VUE NAGLER debuted in 1980 and won wide acclaim among amateur astronomers. Tele Vue produced this eyepiece until 2001, when the 13mm Type 6 replaced it. *ASTRONOMY*: JAMES FORBES

The lunar module simulator included a star field using 1,000 polished steel ball bearings set into a black globe. They were the correct size and in the correct positions to simulate an accurate star field. Al even had a few bearings gold-plated to simulate Antares, Betelgeuse, and several other reddish stars. "You wouldn't believe how much realism just that little bit of color added," he said. Such attention to detail still is one of Al's finest traits.

In 1977, Nagler founded Tele Vue Optics in Spring Valley, New York. There, he began making projection lenses for big-screen television sets. In 1979, Nagler introduced Tele Vue Plössl eyepieces to amateur astronomers, but even though the Plössls received rave reviews, 1980 stands out in the minds of most observers. That was the year the Tele Vue Nagler eyepiece series made its debut.

"I knew the design was the most advanced," said Al Nagler. "What I didn't know was if amateur astronomers would pay that much for an eyepiece." Indeed, $200 was a steep asking price for an eyepiece when other companies at the time were selling "research grade" eyepieces for as little as $39.95.

At this point, Nagler decided to visit star parties and let people try his eyepieces in their telescopes. Later, as Tele Vue became more established, it used the slogan, "even better than you imagined." Well, initial response to the Nagler eyepieces was even better than Al imagined. Observers couldn't believe what they were seeing. The Nagler combined the widest field (82° apparent field of view) with sharp images, not just in the center, but at the field's edge as well.

Since then, both the Nagler eyepieces (in 2003, Tele Vue introduced the Type 6) and the company have evolved. And, in March 1988, Al took a step that guaranteed Tele Vue, Inc., would stay in the family: He hired his son David.

Michael E. Bakich *is an associate editor of* Astronomy.

ASTRONOMY: MICHAEL E. BAKICH

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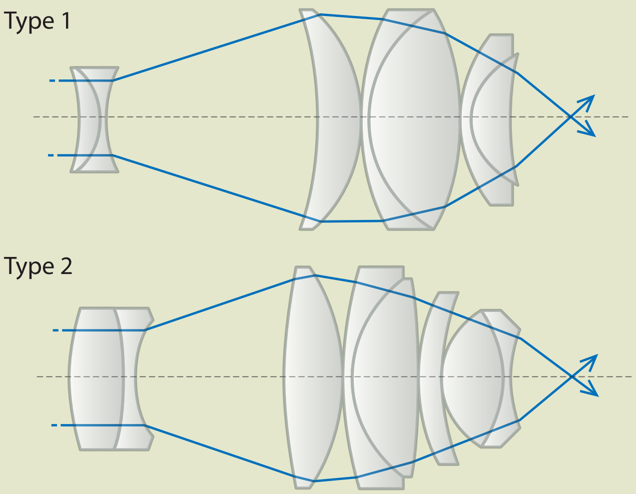


CHANGE IS GOOD. These diagrams show the changes in optical layout between Tele Vue's Type 1 and Type 2 eyepieces.

TELE VUE OPTICS

Family legacy

David Nagler, now Tele Vue's president, recalls the beginning. "Mom and Dad used to sit at the kitchen table boxing up eyepieces to ship," he said. During his college years at Syracuse University, David would come home during breaks and on weekends and put in time at the factory. "I worked as an optics tester. I've personally tested tens of thousands of eyepieces. After I graduated, I realized Tele Vue was where I wanted to be." David, whose degree is in Television, Radio, and Film Production, started writing advertising copy and designing ads for Tele Vue.

"Mom" referenced above is Judi Nagler, who is one of Tele Vue's vice presidents. She met Al in the late 1950s. Their first date was a visit to New York's Hayden Planetarium followed by a concert. "Can you think of a better combination?" asked Al. They married in 1961.

Tele Vue's other vice president is Sandy Nagler, David's wife. The two met at the Alpha Gamma Delta sorority at Syracuse where David was working as a houseboy, and they married in 1992. Sandy worked at Tele Vue from December 1988 until October 1994, then rejoined the company in 2002. Sandy and David have a daughter, Allison, 10, who is ready to head the next generation of Naglers at Tele Vue. "I help out wherever I can," she told me. "I can't wait to start working here for real."

Making optics

Al's first "for sale" telescope was the MPT, which stood for "Multi-Purpose Telescope," a 5-inch f/4 refractor, which was introduced in 1981. Today at Tele Vue, one employee assembles one telescope from start to finish. This instills a sense of accomplishment, and there's no lack of pride among employees. Several times during my visit, I overheard someone say (in response to a specific telescope being mentioned), "That's one of mine," or, "You made that one, didn't you?"

How do employees know which scopes they built? Al explained, "When we receive the warranty card packed with each telescope, we post it here." We were standing in

THE FIRST NAGLER EYEPIECE

On July 3, 1979, Al Nagler completed and dated the original technical drawing for the first of a series of eyepieces to carry his name. In November of that year, he applied for a patent, which was subsequently granted. The 13mm Nagler eyepiece went into production in 1980. Two additional first-generation Nagler eyepieces followed: the 9mm and the 4.8mm. These eyepieces made quite a stir when they were introduced. As well as being the highest-priced eyepiece for amateurs, the 13mm Nagler eyepiece was the first:

- with a dual barrel, both 1¼" and 2"
- with an 82° apparent field of view
- to combine an expanded field of view and sharp images in the center and at the edge
- with eye relief longer than its focal length

— *Michael E. Bakich*

ASTRONOMY: MICHAEL E. BAKICH

AL NAGLER'S DESIGN NOTEBOOK sits open to the page showing the original drawing and specifications for the first Nagler eyepiece. That eyepiece — the 13mm — rests atop the notebook.

ASTRONOMY: MICHAEL E. BAKICH

ASTRONOMY: MICHAEL E. BAKICH

front of a large bulletin board hung, not in an office or a back room, but in the hallway everyone at Tele Vue uses.

After assembly comes optical testing. Each telescope then is cleaned thoroughly. One final optical test — any adjustments are made — and then the scope is packed.

I was surprised at how much is still done "by feel." Several sets of eyes look at a highly magnified image of a false star. Diffraction rings both inside and outside of focus are compared. At any point, anyone can reject the product being tested, sending it back for more adjustment.

"Because we're a small company (20 employees), we can make decisions quickly," said David. "If we can find a better way to do something, we'll do it." To which Al added, "Yes, and cost is not an issue."

Q and A

During my time with Al and David, I asked hundreds of questions. Nothing was off-limits, and they answered every question I asked except one. (More on this later.) Here are a few examples:

I asked David what percentage of their products is used in amateur astronomy, and how much ends up in other applications. "More than 90 percent is used by skygazers," he said. "When we started, it was all for astronomy, but the portability and quality of our small refractors appeal to more and more birders as time goes by."

SCANNING THE EYEPIECE CASE in Al and David Nagler's office is like taking an historical tour through the development of high-quality amateur-astronomy optics.

ASTRONOMY: MICHAEL E. BAKICH

TELE VUE'S OFFICES occupy part of a Chester, New York, industrial park. The building, so far, is nameless. "With a name like Tele Vue, we'd get people asking about television sales or service," said Al Nagler. "It's something we can add in the future, if we choose to."

ASTRONOMY: MICHAEL E. BAKICH

NAGLER 13mm
13mm Nagler

ASTRONOMY: MICHAEL E. BAKICH

To Al, I noted that not every Tele Vue eyepiece is still being made. I asked why a certain eyepiece doesn’t survive. “We discontinue an eyepiece only if we can make a better one of that focal length. We’ve never discontinued anything for lack of sales.”

Moving beyond eyepieces, I asked David which of their accessories has proved most popular. “The Paracorr,” he replied without hesitation. (Note: Tele Vue’s Paracorr is an add-on optical accessory that reduces the optical defect known as coma in “fast,” or short-focal-ratio, reflectors.)

“The idea behind it was that we wanted a reflecting telescope to emulate the flat field of our refractors. We wanted to get rid of the coma, but not introduce any other [optical] flaws.” Al added: “The Paracorr showed a limitation in our Wide Field model eyepiece series. When it removed the coma, it revealed some astigmatism, which led to the Panoptic design.”

David continued, “The Paracorr, along with our Nagler eyepieces, complemented what’s been called the Dobsonian revolution, which began in the 1980s, perfectly. People were using short-focal-ratio reflectors, and we provided ways to help them get the most from their investment.”

At one point, Al and I were walking through the ample warehouse. Tele Vue stocks at least a 6-month supply of most products because they don’t want to run into any shipping-related issues with their suppliers. I asked if many eyepieces were returned. “Quite a few,” he replied. Having seen Tele Vue’s quality-control up close, I was surprised at this answer until Al continued, “They’ve been dropped, scratched, or had something bad happen to them. They come back here for repair.” But are any eyepieces returned for quality issues? “Less than one in 5,000,” Al beamed.

I asked David how changes in amateur astronomy have impacted Tele Vue. He replied, “It’s easy to design a product in a vacuum. However, with the variety of existing equipment a new product will interact with, it’s increasingly difficult to satisfy all applications with the high-performance standards a Tele Vue product must possess.”

In 1979, Al was awarded a patent for his Plössl eyepieces. I asked how the Nagler design developed from them. “Actually,” Al replied, “I designed the Naglers first. But it was such a radical design with its wide field of view and sharp images. At the time, Tele

/// LET’S HAVE A CONTEST

In 1984, Al Nagler designed a telescope. Al said, “If I’m ever going to make it with a telescope, it’s going to be at the time of Halley’s Comet!” Unlike other products Nagler introduced, he wasn’t certain the scope would sell. “We chose brass for the tube in case sales were bad,” Al said. “We knew we could sell them to designers.” And thus was born ... but wait! The new scope lacked a name.

“We actually looked on this as an opportunity to generate some press for the introduction of the telescope,” said Al.

So a contest was announced to name Tele Vue’s new scope. First prize, fittingly, was one of the telescopes. The response was great, but none of the names really appealed to Al or his staff.

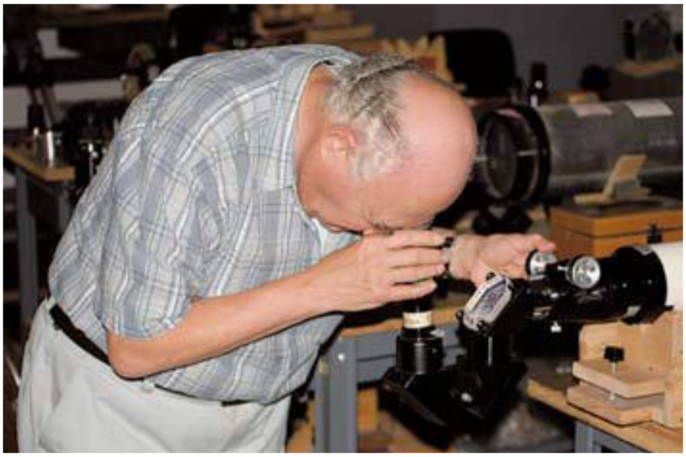
“We were sitting around one day,” David said, “when Dad announced, ‘I have the perfect name — Renaissance!’ It was perfect, too, embodying what the scope was. But the contest was on, and somebody had to win.”

Luckily, as the contest deadline approached, someone sent in the chosen name. The following day, someone else suggested Renaissance. What to do? “We solved it the only way we could. We gave them both telescopes,” said Al. — *M. E. B.*

ASTRONOMY: MICHAEL E. BAKICH

TELESCOPE WARRANTY CARDS, and especially their customer comments, occupy a prominent location at Tele Vue.

TELE VUE OPTICS



ASTRONOMY: MICHAEL E. BAKICH

Vue wasn't well-known to amateur astronomers, so I didn't know if I could sell eyepieces — no matter how good — that cost a lot more than available eyepieces without more name recognition. So I designed a line of Plössls, built up good reviews and good word of mouth from observers, and when I thought the time was right, I introduced the Nagler." Since then, amateur astronomy hasn't been the same.

By now, you may be wondering what my unanswered question was. I asked it while chatting in Al and David's office: Why are there no Nagler Type 3 eyepieces?

"There just aren't any," replied Al, "We came out with the Type 4 in 1997." Having spent several days with the driving forces behind Tele Vue, I was pretty certain they never did anything without a reason, so I followed up with, "Why didn't you call the Type 4 series the Type 3?" Al's two-part reply was both cryptic ("We have to have some secrets.") and challenging ("That's all I'm saying. If you can get David to tell you, I'm OK with that.") I turned to David, but the look in his eye wasn't inviting. Perhaps I'll wait until the 50th anniversary of the Nagler to ask the question again.

And the beat goes on

"What's the best thing about running Tele Vue?" I asked both Al and David. Both replied so quickly that I have trouble remembering which of them made a certain point. But I remember what they said: "The freedom to do what we want, when we want, and for the right reasons. The joy of working with like-minded people. The thrill of breaking new ground, doing something that hasn't been done before. And, above all, the satisfaction of knowing our customers are having a great experience."

This last point was made obvious many times during my visit, when a voice from the front office would announce over the intercom, "Al or David, technical question on [telephone] line 1."

One call Al fielded went on for more than 10 minutes. Finally, the customer expressed his gratitude and asked who he'd been speaking to. "This is Al," was the reply. The customer thanked Al again and then commented on how owning Tele Vue equipment has made his hobby more enjoyable. Al related all this to me. Then, as a large smile crossed his face, he said, "That's what it's all about. A

ASTRONOMY: MICHAEL E. BAKICH

MANY CORPORATE EXECUTIVES spend their days in long, boring meetings. At Tele Vue, you're likely to find the company president (David Nagler, left) and CEO (Al Nagler) fielding calls from customers. Their office's "dual-desk" setup allows for rapid (and occasionally high-volume) exchanges of ideas. "It's a system that works well," said David. "It lets us make decisions quickly."

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EQUIPMENT REVIEW

Set up this simple solar viewer, and you're sure to attract a crowd.

/// BY RAYMOND SHUBINSKI

Follow the daytime star

Planetarium professionals, teachers, and other educators have always had a thorny problem with observing: Most students are available only during daylight hours. It's difficult to get students together for an evening under the stars. One option is to view the Sun. Although viewing our star can be dangerous, a number of safe methods exist. These include handheld or telescope-mounted filters and pinhole projection. The ideal product for sun-viewing would combine safety and low cost, and now you can buy such an instrument. It's called Solarscope. Solarscope was invented by astronomer Jean Gay from the Cote d'Azur Observatory in Nice, France, as an easy way for groups to view the Sun.

The product is light-years ahead of a cardboard box that uses pinhole projection, but it stops just short of being a telescope. It's safer than projecting through a telescope (inexperienced observers may look through the scope), and it's less expensive than using Hydrogen-alpha filters.

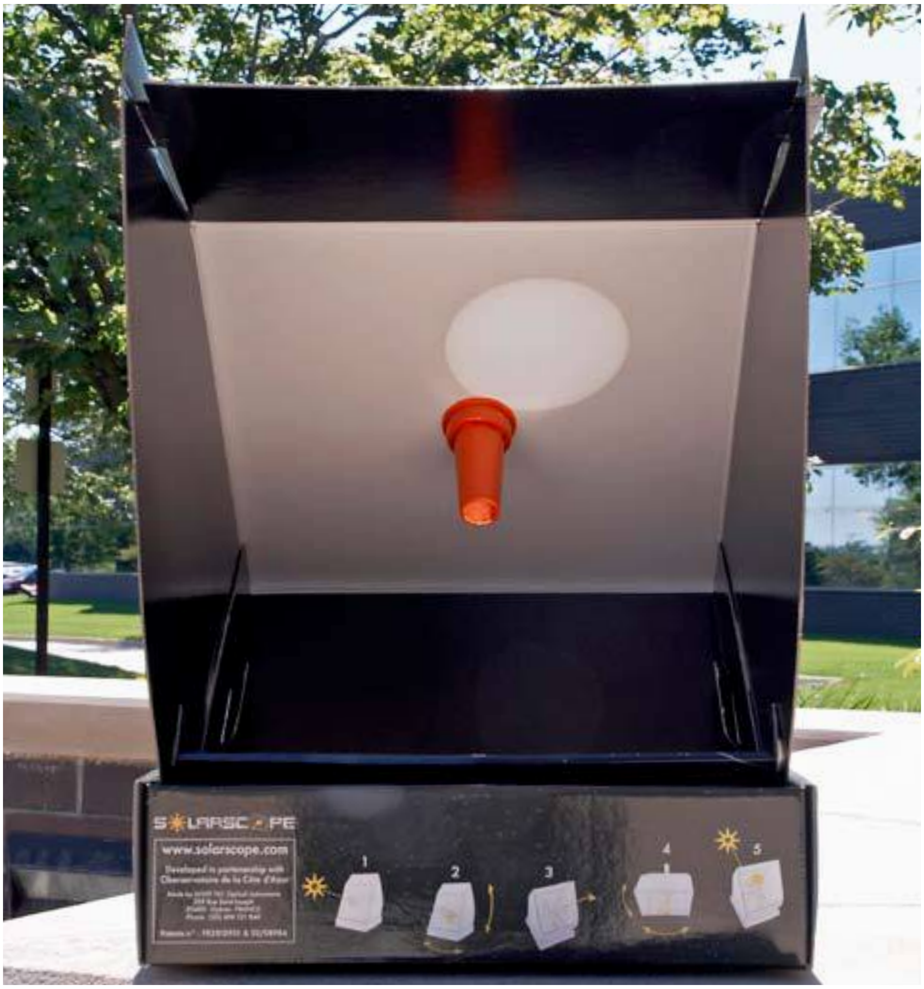
The viewer comes in two sizes and is made of sturdy cardboard. Some assembly is required. A booklet shows how the parts fit. As with a pinhole-projection system, you need a shaded viewing area. With the Solarscope's cleverly designed base and hood assembly, the Sun's image can be viewed in a large darkened area by a group.

The Solarscope's optics set this viewer apart. During assembly, a mirror inserts into an aluminum holding device. This snaps into the base of the Solarscope. Because of the mirror's shape, the Sun's image is offset inside the box.

The other optical portion is a simple "telescope" made of a plastic tube with a front lens, but without an eyepiece. The telescope attaches to the hood. To focus, simply screw the telescope in or out.

Once you fit the base-with-the-mirror and the hood-with-the-telescope together, you're ready to observe. It took me about 10 minutes to assemble the Solarscope.

Using it is easy. Set the assembled instrument on a table or stand to make the Sun easier to see. To point it, move the hood with the telescope up or down while turning the base side to side until the telescope points at the Sun.



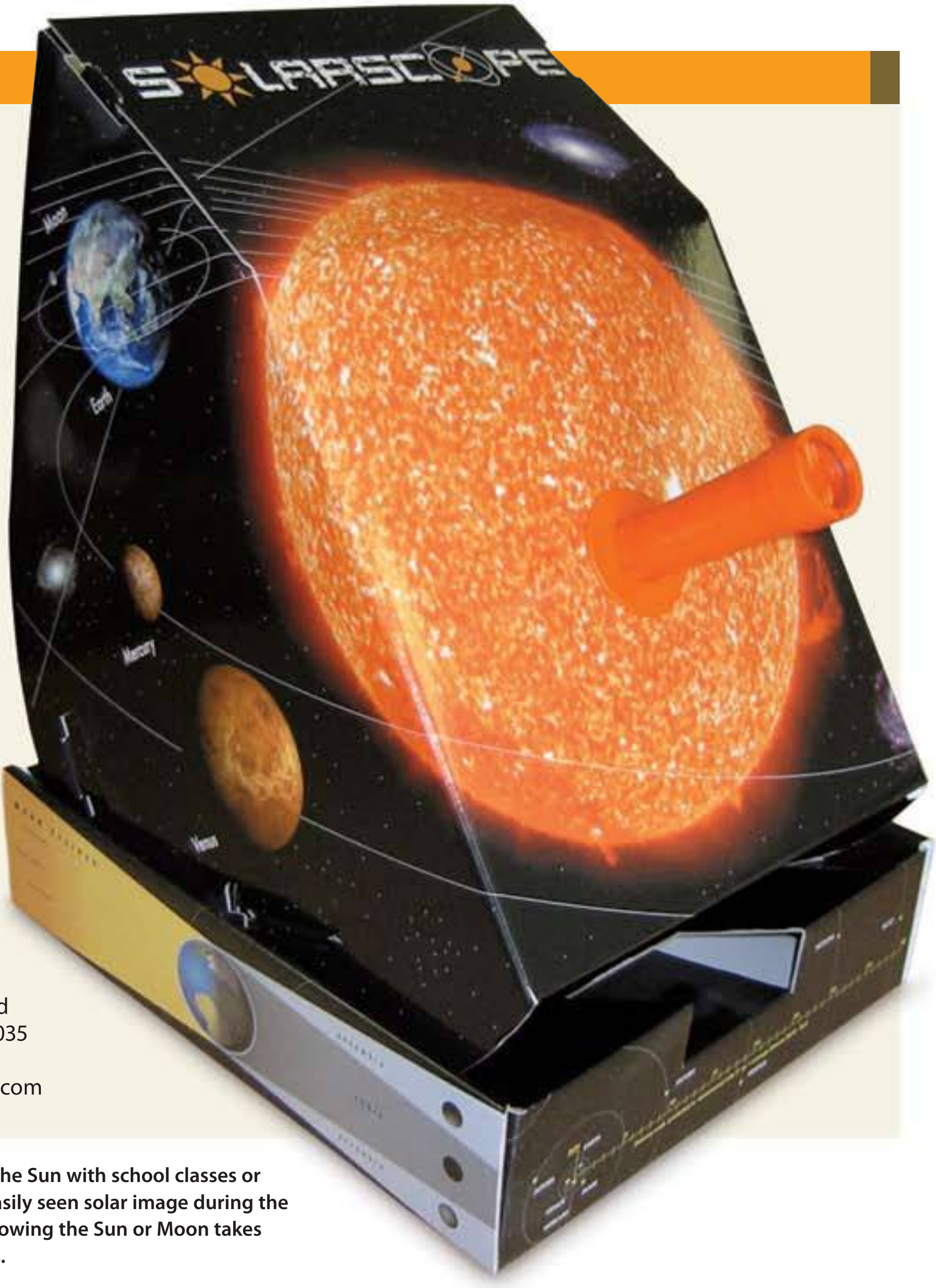
ALL IMAGES: *ASTRONOMY*: WILLIAM ZUBACK

POINT THE SOLARSCOPE at the Sun, and make sure the focused beam falls on the small spherical mirror in the base. Adjust the angle slightly so the Sun's image is off-center, and look for sunspots. Because you can't look directly at the Sun through this device, there's no threat of eye injury.

/// PRODUCT SPECIFICATIONS

SOLARSCOPE

Materials:	Colored, labeled cardboard; glass lens and mirror; plastic and aluminum mechanical mounts
Lens aperture:	1.6" (40 millimeters)
Sun's image:	approx. 3.2" (80mm) in diameter (Individual model); approx. 4" (100mm) in diameter (Education model)
Screen size:	9.4" (240mm) square (Individual model); 14" (356mm) square (Education model)
Price:	$59 (Individual model); $89 (Education model)
Contact info:	Solarscope LLC 1350 Old Skokie Road Highland Park, IL 60035 [t] 847.579.0025 [w] www.solarscope.com



THE SOLARSCOPE is perfect for viewing the Sun with school classes or public groups. Its optics project a large, easily seen solar image during the day or the Full Moon's image at night. Following the Sun or Moon takes only small adjustments every few minutes.

Once you've found the Sun, the box's interior lights up. Keep moving the box until the beam of sunlight hits the mirror. Rotate the mirror slightly to throw the Sun's image to either side of the telescope.

The Solarscope shows even medium-size sunspots. The Sun currently is at a solar-activity minimum, but during the past year, there have been surprises.

Watching the Sun move across the box's inside is a nice way to demonstrate Earth's daily motion. Eventually the planet rotates enough that you have to realign the Solarscope on the Sun. Simple movements toward the west and either up or down are all that's required. If teachers want to use multiple Solarscopes, students can operate them without fear of eye damage.

Solarscopes also can be used as Moonscopes. The lens collects just enough light and provides just enough magnification to view a bright Moon. The projected image (the same size as the Sun's) inside the hood shows the Full Moon's major features easily, allowing you to point out maria, highlands, and cratered areas.

Solarscope maintains a web site at www.solarscope.com that provides helpful ideas, information, and projects.

For a small investment, Solarscope is a great way to view the Sun. Solarscope comes in two sizes, so it's useful for either one person or a group. The Solarscope also looks great. The base and hood are covered with astronomical images and information, so you can learn a lot of astronomy even before you take it outside.

This clever instrument gets two thumbs up from me. It may be made of cardboard and plastic, but it should have a place right next to your telescope.

Raymond Shubinski *is the director of the East Kentucky Science Center, from where thousands of visitors have viewed the Sun.*

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Case for RCX 12" scope under development

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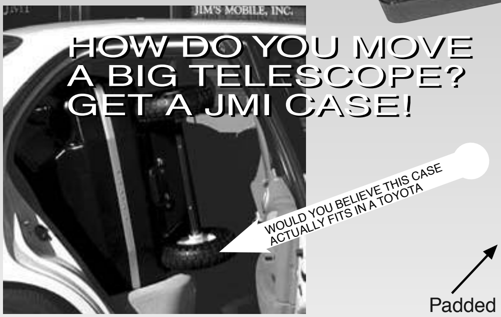
$500 Price increase on the RB-16 January 1, 2006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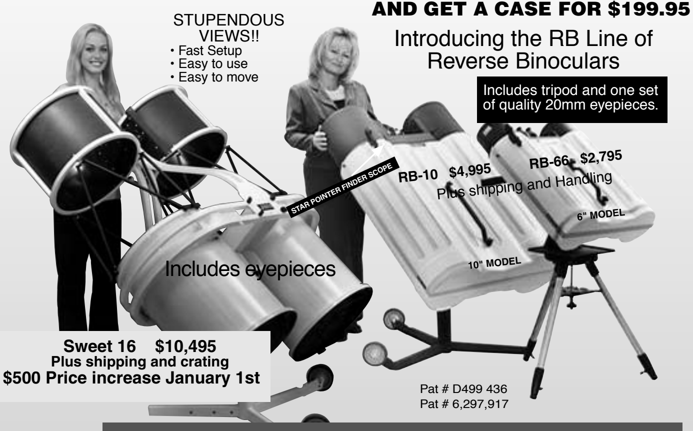

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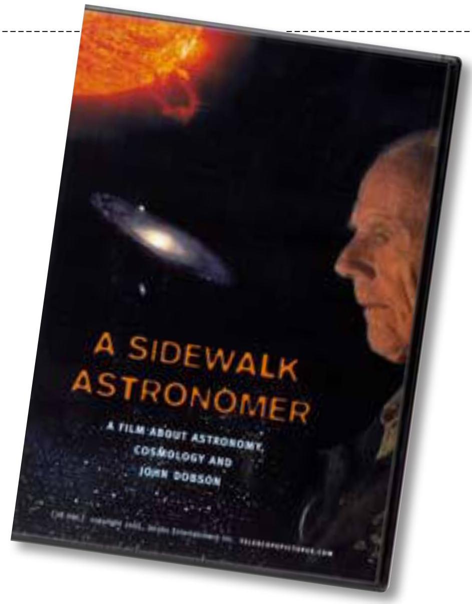

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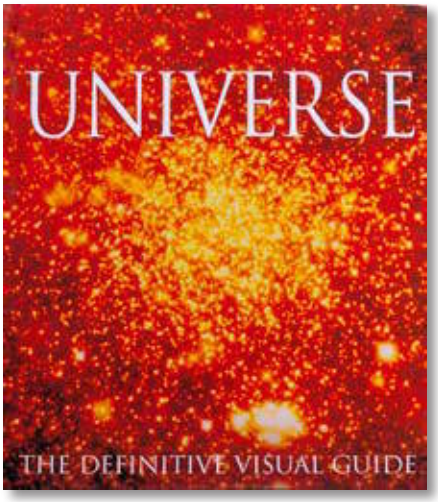

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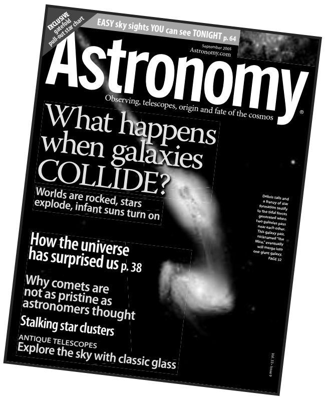

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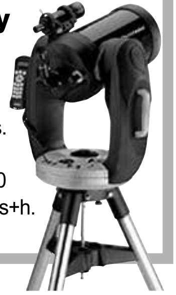

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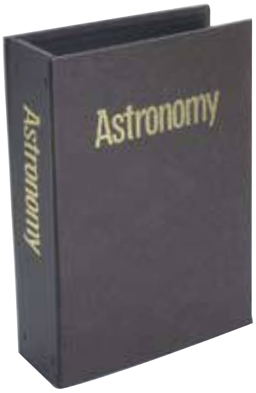

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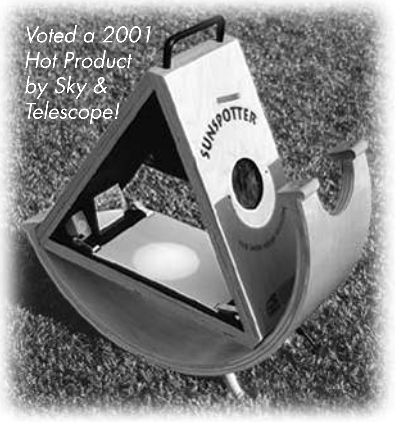

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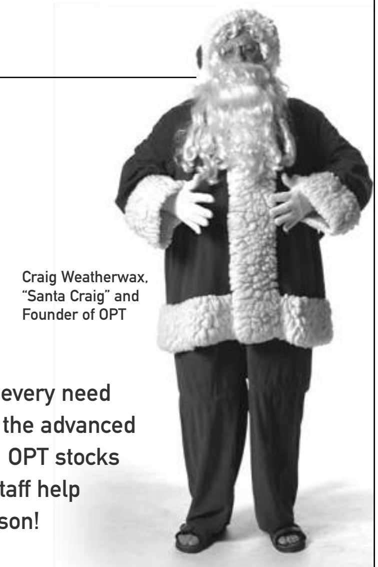

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Top 10 astronomy stories
Cassini-Huygens reaches Saturn, Deep Impact smacks a comet, the Andromeda Galaxy beefs up, and the shuttle returns to flight — these and other astronomy stories made headlines in 2005.

Fugitive star
A century ago, this runaway star named for Dutch astronomer Jacobus Kapteyn helped uncover the Milky Way's structure.

Stellar-code safecracker
Cecilia Payne-Gaposchkin laid the foundation of stellar astrophysics, fusing astronomy and the world of atoms.

The greatest nebula
The Orion Nebula is one of the showpiece celestial objects. Although astronomers have observed it for hundreds of years, it still has secrets to divulge.

Saturn spectacular
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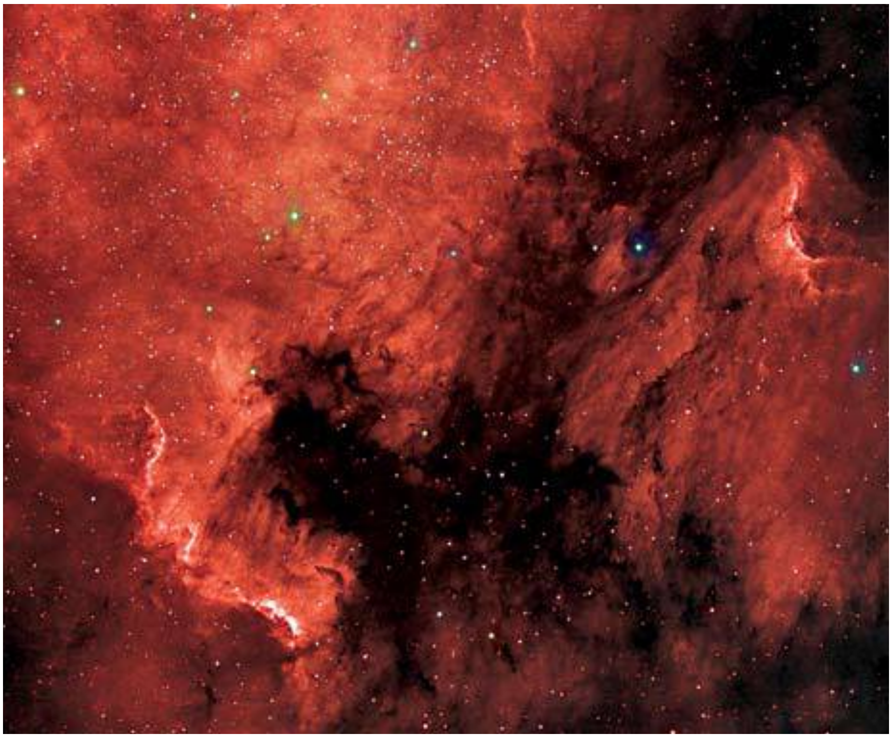
Cold winter temperatures force many astronomers indoors and drive attention away from the night sky. During this season, the last thing on an observer's mind is gathering with others to hunt deep-sky objects, swap instrument tips, or tour a scope field.



JAY BALLAUER

SPRING AND SUMMER STAR PARTIES can provide amazing views. This North America and Pelican nebulae image, captured during the 2004 Texas Star Party, shows what great conditions, trusted equipment, and practice can do for your imagery.

And for good reason — very few clubs, even those in warmer climates, host outdoor events during winter.

While spring and summer star parties may seem an ice age away, don't hesitate to make plans now. Many of the major events require reservations months ahead.

Don't miss out on incredible observing opportunities in the upcoming year. Here are a few popular star parties to consider:

APRIL 20–23, 2006

Georgia Sky View

Indian Springs State Park, near Jackson, Georgia. Hosted by the Flint River Astronomy Club, this is a popular observing weekend for Dixie stargazers who don't want to venture farther south for Florida star parties. For more information, visit www.flintriverastronomy.org.

APRIL 23–30

Texas Star Party

Prude Ranch, near Fort Davis, Texas. This event is known for its no-nonsense observing atmosphere. To ensure a high-quality experience, attendance is limited. In addition to skywatching, activities include tours of McDonald Observatory, lectures, workshops, competitions, and a swap meet. The deadline for entering the registration lottery is mid-January. The drawing will occur in late-January. For more information, visit www.texasstarparty.org.

MAY 26–28

Riverside Telescope Makers Conference

YMCA Camp Oakes, near Big Bear City, California. RTMC is usually the most popular astronomy gathering in the Golden State. The theme for this year's conference is "Preserving and Enjoying the Night Sky." With clear, high-altitude observing, informative lectures, and productive workshops, there is no doubt why this event has drawn stargazers from around the world. For more information, visit www.rtmcastronomyexpo.org.

JUNE 22–26

Cherry Springs Star Party

Cherry Springs State Park, Galeton, Pennsylvania. Along with dark skies, this state park provides terrific camper amenities, like running water and electric hookups. For more information, e-mail president@astrohgb.org; web site, www.cherrysprings.org.

JUNE 22–25

Rocky Mountain Star Stare

Pike National Forest, near Colorado Springs, Colorado. The high elevation will provide incredible views at night. Workshops, lectures, and contests will be held during the day. For more information, call Alan Gorski at 719.651.8476; web site, www.rmss.org.

JULY 20–22

Table Mountain Star Party

Table Mountain, near Ellensburg, Washington. The highlights will be dark-sky observing, workshops, and lectures from prominent figures in the astronomical community. Attendance at the star party is restricted to 700 people, so register as soon as possible. For more information, e-mail imround830@aol.com; web site, www.tmspa.com.

Can't wait for spring or summer? Here are a few winter star-party destinations:

FEBRUARY 20–26

Winter Star Party

Camp Wesumkee, West Summerland Key, Florida. Sponsored by the Southern Cross Astronomical Society. The 12-hour observing sessions at this dark-sky site will provide ample time to target celestial beauties. Avoid a $15 fee by registering before November 15. For more information, visit www.scas.org.

FEBRUARY 22–26

Deep South Texas Stargaze

Escondido Ranch, McMullen County, Texas. Hosted by the Kingsville Astronomical Society, this gathering is held under nearly 7th-magnitude dark skies. Climate-controlled bunkrooms with showers are available as well as camping and RV sites. In addition to observing, there will be speakers and door prizes. For more information, e-mail Jason Fry at dstsreg@hotmail.com, web site, www.geocities.com/kingsville_astronomical_society/dsts.htm.

FEBRUARY 22–26

Orange Blossom Special Star Party

Alafia River State Park, Lithia, Florida. Although it is easily accessible from Tampa, this site offers tremendously dark skies. Besides observing, there will be other family-oriented activities, including a hayride, music jam session, and group hike along the park's trails. Register before December 31 to avoid late fees. No walk-ins will be permitted. For more information, call 813.792.0721; e-mail, dnefarr@msn.com; web site, home1.gte.net/hoffmanc.

CONTACT INFORMATION

Please submit club announcements 4 months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Also use this e-mail address to submit your events for our online calendar.

INDEX *of* ADVERTISERS

20-20 Telescopes 97
Adirondack Video Astronomy 97
Adorama 74, 75, 97
Anacortes Telescope and Wild Bird 25, 97
Analytical Scientific 114
Ash Manufacturing 111
Astro Haven 115
Astro-Physics 116
Astrographics Publishing 110
Astronomics 70-71, 97, 111
Astronomy.com 110
Astronomy binders 106
Astronomy magazine 108, 113
Astronomy magazine winter sweeps 10-11
Atomic Time 107
Beam of Light Technologies 115
Beta Electronics 114
Bethany Sciences 116
Binoculars.com 97, 116
CStar Optics, Inc 114
Camcor, Inc. 105
Camera Bug 111
Camera Concepts 97
Celestron 121
Coronado Instrument Group 7
Cosmos Apparel 106
Dark Sky, Inc 116
Denkmeier Optical 115
Discovery Telescopes, Inc. 97
Earthshine Technologies LLC 114
Eclipse Tours 111
Equatorial Platforms 115
Flagstaff Convention & Visitors Bureau 103
Galileo Optics 114
Glatter, Howard 114
Hands on Optics 106
High Point Scientific 97
Innovations in Travel 116
Into the Wind/The Kite Source 116
Jacobs Entertainment 111
Jim's Mobile Inc 100
Johnsonian Designs 114
Konus 31
Learning Technologies Inc 106
Lumicon 34
Lymax Earth, Sky, & Astronomy 97
Marketplace Pages 114-116
Max Factory 115
Meade Instruments Corp 2, 3, 8, 9, 12, 13, 28, 29, 17, 19, 122
Observa-Tech 116
Oceanside Photo & Telescope 97, 103, 106
Opticsplanet, Inc 97
Orion Telescopes & Binoculars 96, 97, 101
Owl Services 112
Pegasus Optics 114
Peterson Engineering 115
PolarisUSA Video Inc. 81
Rainbow Symphony 116
Ritz Camera Superstores 97, 115
Rivers Camera Shop 97, 105
S&S Optika 97
SAC Imaging Systems 112
SCS Astro 106
Scope Buggy 112
Scope City 27, 97
Scope Stuff 112
Scopes4Rent 114
ScopeTronix 59, 97
Skies Unlimited 97
Sky Watchers Inn 114
SLOOH 80
SmartAstronomy.com 112
Software Bisque, Inc 32, 33
Solarscope 112
Stargazers Inn 115
Starizona 97, 110
StarGPS 114
Stellarvue 107
Streamtrade International 112
T&T Binocular Mounts & Beyond LLC 112
Technical Innovations 110
Tele Vue dealer page 97
Televue Optics, Inc. 23
The Teaching Company 35
Van Slyke Engineering 112
Vixen 21
Website Directory 74
Wicked Lasers 102
William Optics Co. 81
Woodland Hills Photo Images 81, 97
www.bigbinoculars.com 115
Yankee Robotics 114
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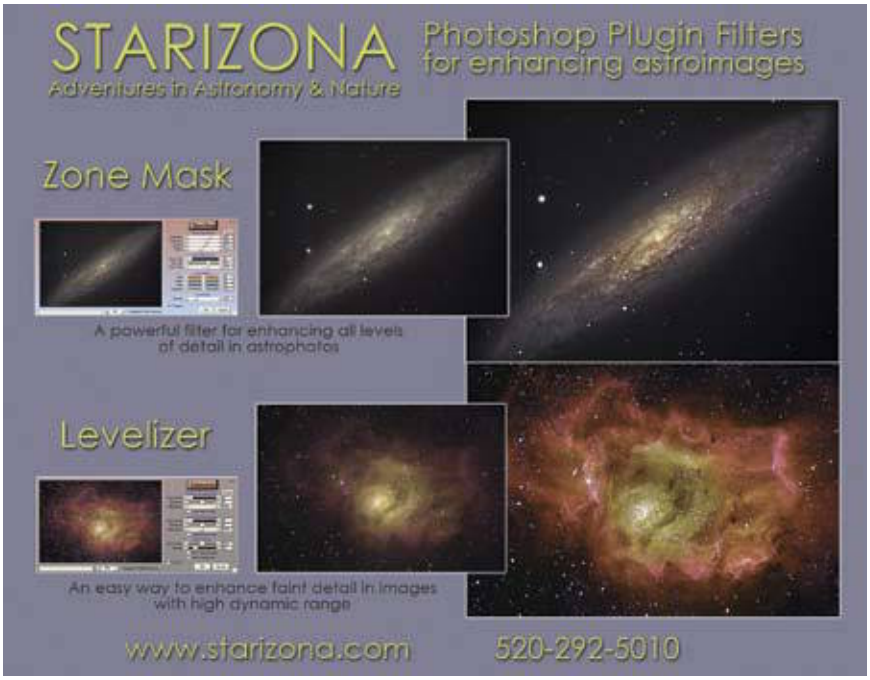
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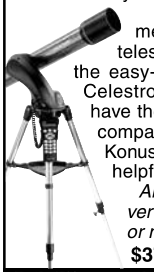

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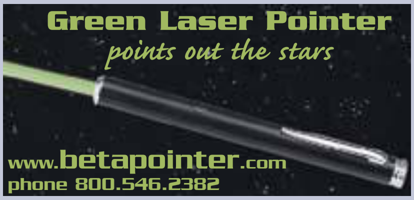

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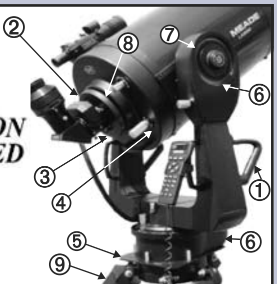

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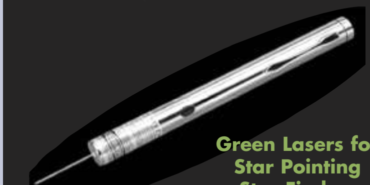

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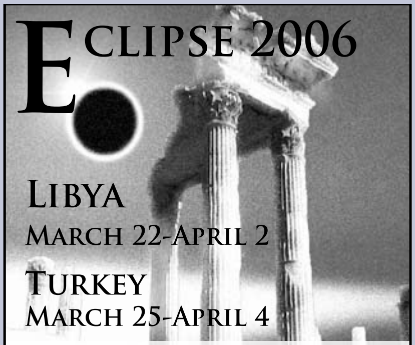

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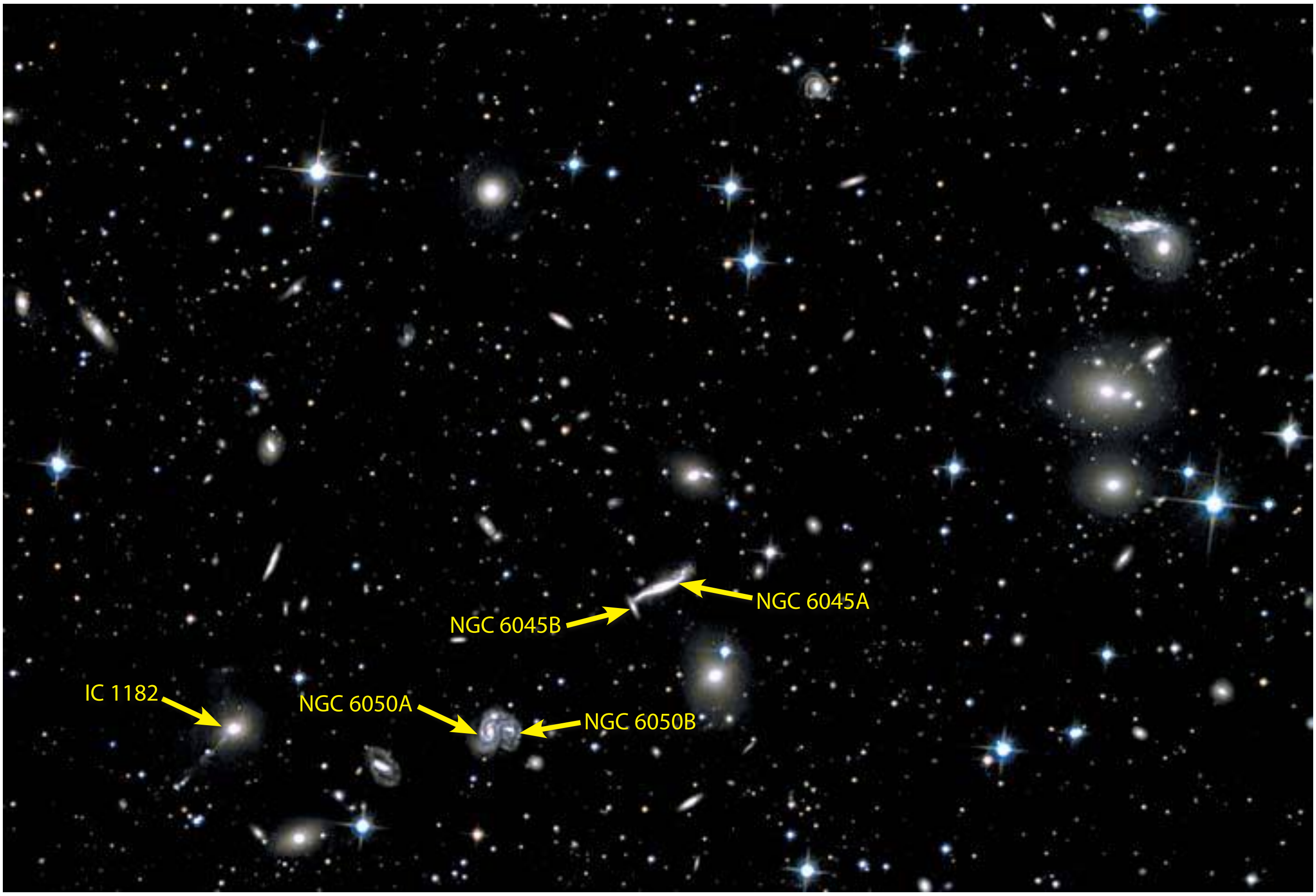

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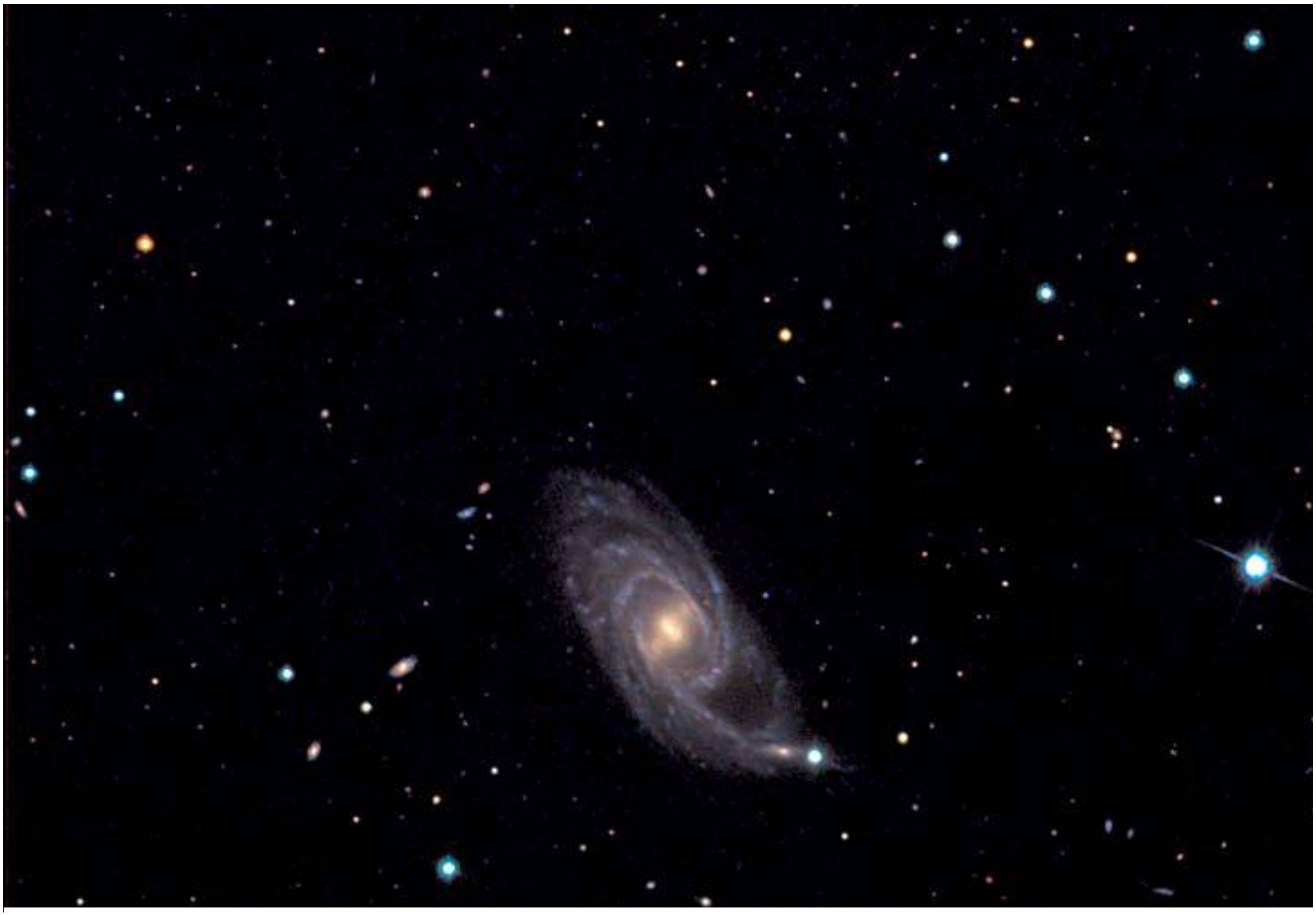
Abell 2151

The Hercules Galaxy Cluster (Abell 2151) is irregular and rich in spiral galaxies. It lies 700 million light-years from Earth. The designation "Abell 2151" comes from a catalog of roughly 4,000 galaxy clusters compiled by American astronomer George Abell in 1958. The cluster contains some 80 galaxies, with many interacting pairs.

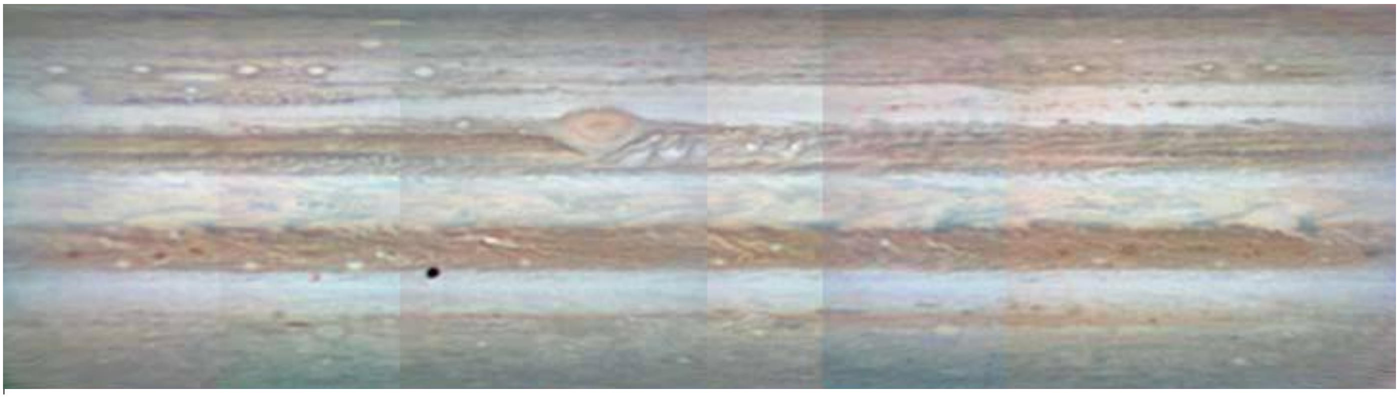
One spiral pair is NGC 6050A and NGC 6050B. The result of an extreme interaction is seen in IC 1182, which has a long blue tail formed by tidal interaction and a shell of accreted stars and gas. The edge-on galaxy NGC 6045A shows a warped disk from a past interaction with NGC 6045B.

ABELL 2151 (20-inch RC Optical Systems Ritchey-Chrétien reflector, Yankee Robotics Trifid II 6303E CCD camera, Astrodon filters, LRGB image with exposures of 180, 74, 74, and 74 minutes, respectively)
/// **KEN CRAWFORD, CAMINO, CALIFORNIA**

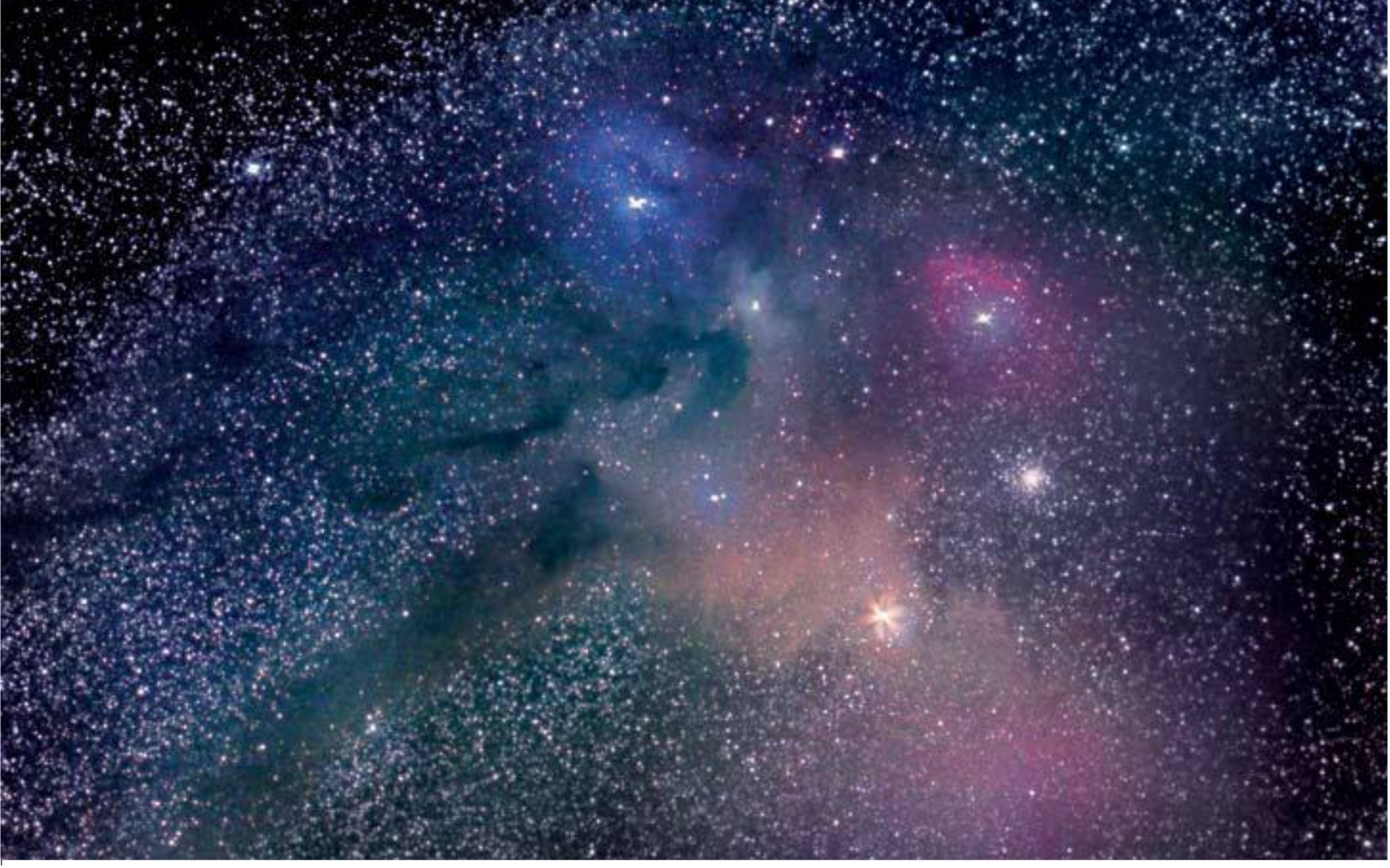
Send your photos to: *Astronomy* Reader gallery, P. O. Box 1612, Waukesha, WI 53187; e-mail to readergallery@astronomy.com. Please include your full name, date and location of image, and complete photo data: telescope, camera, film, and exposure information.



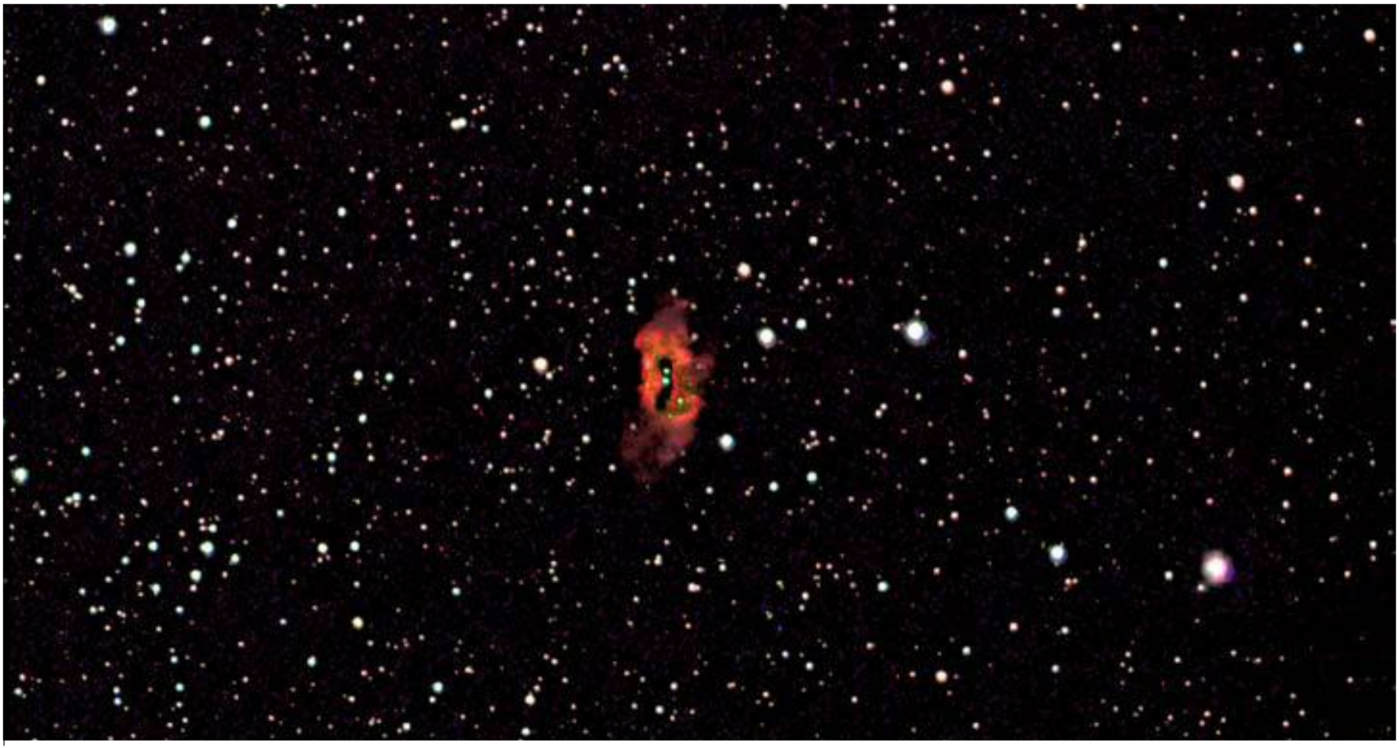
SPIRAL GALAXY NGC 151 lies in Cetus, 160 million light-years from Earth. The galaxy's purplish appearance indicates the bluish spiral arms contain many red hydrogen clouds. At NGC 151's distance, however, these features do not resolve well. (20-inch RC Optical Systems Ritchey-Chrétien reflector at f/8.4, SBIG ST-10XME CCD camera, LRGB image with exposures of 90, 20, 20, and 20 minutes, respectively) /// **PAT AND CHRIS LEE/ADAM BLOCK/ NOAO/AURA/NSF, KITT PEAK NATIONAL OBSERVATORY**



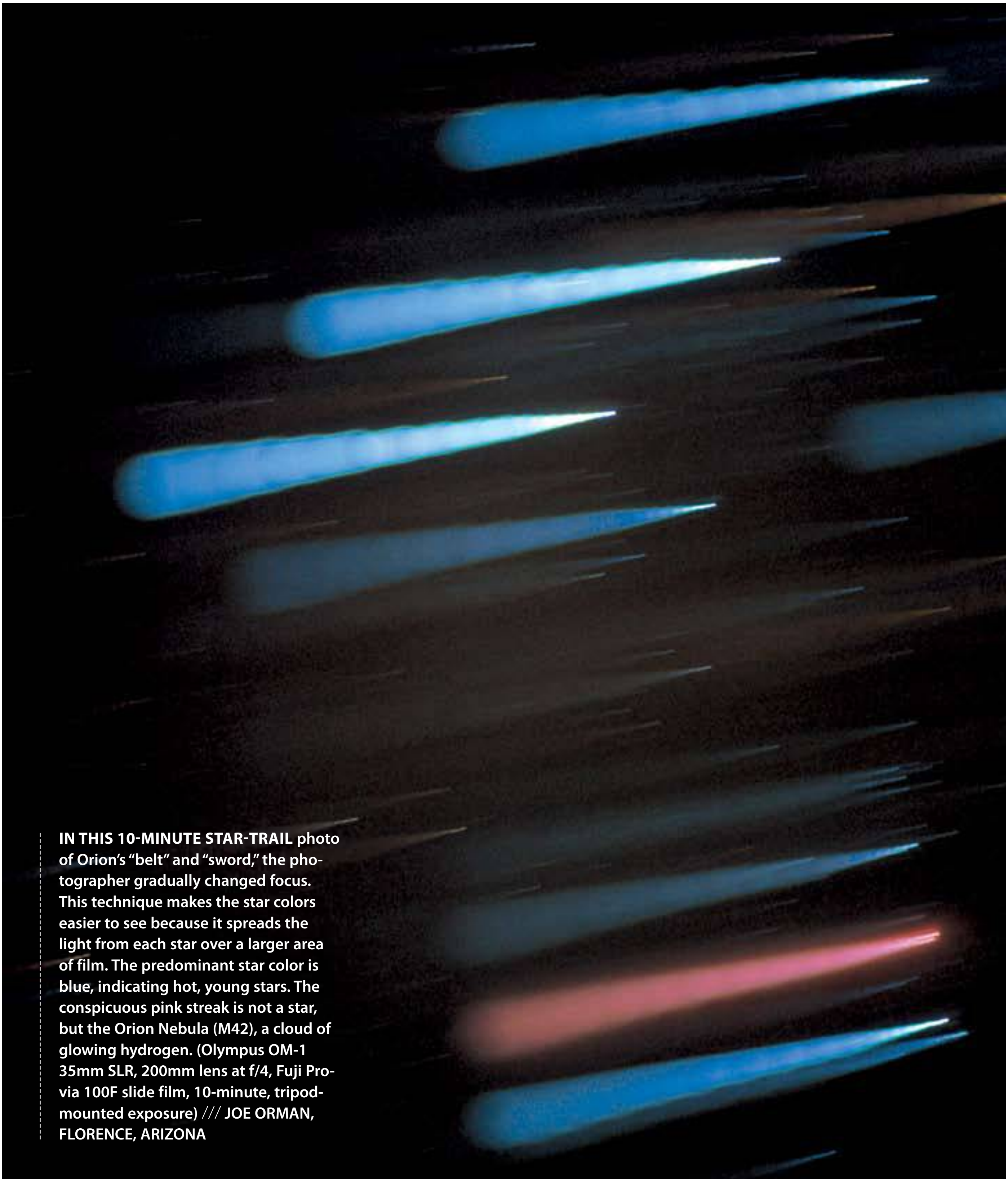
TO CREATE A JUPITER MAP, start by taking many images. Then, use computer software to process the raw images, stretch them into the proper orientation, and stitch them together. This image shows many jovian atmospheric features, including the Great Red Spot to the upper left of center. (9.25-inch Celestron Schmidt-Cassegrain telescope at f/42, Lumenera LU075 video camera, series of exposures taken April 25 and 26, 2005) /// **DAMIAN PEACH, ST. PHILIP, BARBADOS**



THE REGION AROUND ANTARES (Alpha [α] Scorpii) is one of the sky's most active — and most colorful. Reddish-orange Antares sits to the lower right of center. To its upper right, globular cluster M4 shines. Dust and cold gas comprise the dark areas so apparent in this image. (Kaleidar 150mm f/2.8 medium-format lens at f/5.6, SBIG STL-6303 CCD camera, Astrodon filters, LRGB image with two 5-minute exposures in each channel) /// **PAOLO CANDY, CIMINI ASTRONOMICAL OBSERVATORY, SORIANO NEL CIMINO, ITALY**



PLANETARY NEBULA SHARPLESS 2–71 lies in Aquila the Eagle. This object was cataloged originally as an emission nebula, and it's easy to see why. (8-inch Intes Micro Maksutov-Newtonian telescope, SBIG ST-2000XM CCD camera, LRGB image with exposures of 120, 60, 50, and 50 minutes, respectively) /// **DEAN SALMAN, TUCSON, ARIZONA**



IN THIS 10-MINUTE STAR-TRAIL photo of Orion's "belt" and "sword," the photographer gradually changed focus. This technique makes the star colors easier to see because it spreads the light from each star over a larger area of film. The predominant star color is blue, indicating hot, young stars. The conspicuous pink streak is not a star, but the Orion Nebula (M42), a cloud of glowing hydrogen. (Olympus OM-1 35mm SLR, 200mm lens at f/4, Fuji Provia 100F slide film, 10-minute, tripod-mounted exposure) /// JOE ORMAN, FLORENCE, ARIZONA

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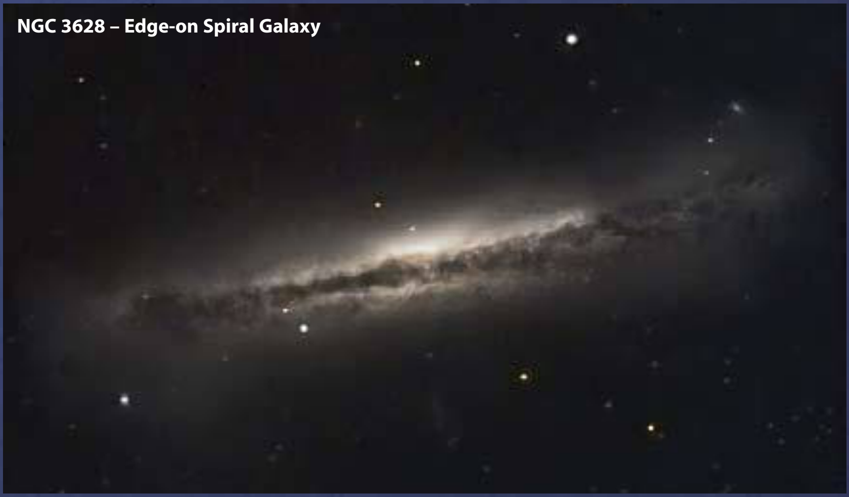
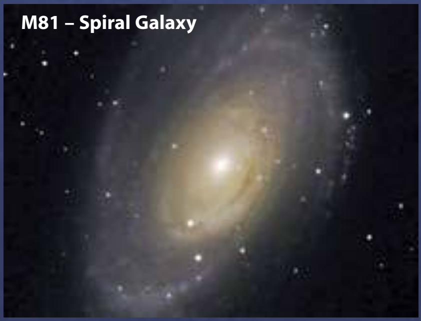
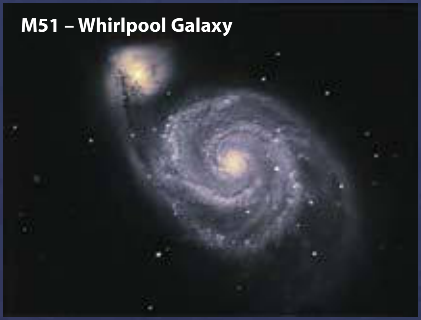


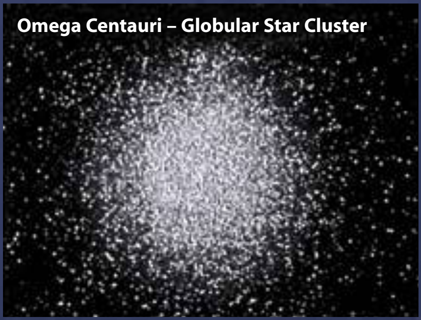
NGC 3628 – Edge-on Spiral Galaxy



M81 – Spiral Galaxy



M51 – Whirlpool Galaxy



Omega Centauri – Globular Star Cluster

M81 *by Mark Sibole – Fife Lake, Michigan*
@ f/6.3. 6 x 180 seconds.

NGC 3628 *by Chuck Domaracki – Memphis, MI*
@ f/5.5. 186 minutes total exposure.

M51 *by Chuck Reese – Prior Lake, MN*
@ f/5. 152 x 1 minute.

Omega Centauri *by Jean-Paul Longchamp – Mahina, Tahiti*
@ f/10. 272 x 10 seconds.

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